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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(21) International Application Number: <b>PCT/US91/07150</b> (22) International Filing Date: <b>27 September 1991 (27.09.91)</b> (30) Priority data: 589,928                      1 October 1990 (01.10.90)      US 722,322                      28 June 1991 (28.06.91)              US (71) Applicant: <b>BOARD OF REGENTS, THE UNIVERSITY OF TEXAS SYSTEM [US/US]; 201 West 7th Street, Austin, TX 78701 (US).</b> (72) Inventors: <b>YANG, David ; 13315 Rosstown Drive, Sugarland, TX 77478 (US). WALLACE, Sidney ; 3324 Pittsburg, Houston, TX 77005 (US).</b> (74) Agent: <b>MAYFIELD, Denise, L.; Arnold, White &amp; Durkee, P.O. Box 4433, Houston, TX 77210 (US).</b>		(81) Designated States: <b>AT, AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CA, CF (OAPI patent), CG (OAPI patent), CH, CH (European patent), CI (OAPI patent), CM (OAPI patent), CS, DE, DE (European patent), DK, DK (European patent), ES, ES (European patent), FI, FR (European patent), GA (OAPI patent), GB, GB (European patent), GN (OAPI patent), GR (European patent), HU, IT (European patent), JP, KP, KR, LK, LU, LU (European patent), MC, MG, ML (OAPI patent), MN, MR (OAPI patent), MW, NL, NL (European patent), NO, PL, RO, SD, SE, SE (European patent), SN (OAPI patent), SU*, TD (OAPI patent), TG (OAPI patent).</b>  <b>Published</b> <i>With international search report.</i> <i>With amended claims and statement.</i>	
(54) Title: <b>HIGH AFFINITY TAMOXIFEN DERIVATIVES AND USES THEREOF</b>			
(57) Abstract <p>Applicants describe the synthesis of tamoxifen derivatives, most particularly halo, halo alkyl and hydroxy tamoxifen derivatives, wherein with the native tamoxifen molecule includes a substituted chemical group positioned on the aliphatic chain of the tamoxifen molecule. Particular halogenated tamoxifen derivatives of the invention include chloro, bromo, iodo and fluoro tamoxifen derivatives, and corresponding lower alkyl halogenated forms. The halogenated tamoxifen derivatives possess superior binding affinities for estrogen receptor rich tissues, such as uterine tissue and breast tissue, relative to unsubstituted native tamoxifen. In particular, the fluoro and bromo tamoxifen derivatives have potential use in imaging estrogen receptors by PET whereas the iodinated tamoxifens have potential use in imaging estrogen receptors by SPECT. The bromomethyl tamoxifen derivatives are demonstrated to bind estrogen receptors with the greatest enhancement of binding affinity over native tamoxifen. Rapid and efficient methods of preparing the tamoxifen derivatives having high specific activity (&gt; 6 Ci/μmol) are also disclosed. Aliphatic chain substituted tamoxifen derivatives are shown to possess greater estrogen receptor binding affinity and more potent tumor cell inhibition than tamoxifen or tamoxifen derivatives substituted at other locations on the molecule (i.e., non-aliphatic chain substituted tamoxifen). The tamoxifen derivatives of the present invention may advantageously be used as anticancer therapeutic agents to halt estrogen-receptor positive tumors, such as those of breast and uterine tissue.</p>			

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<p>(54) Title: HIGH AFFINITY TAMOXIFEN DERIVATIVES AND USES THEREOF</p> <p>(57) Abstract</p> <p>Applicants describe the synthesis of tamoxifen derivatives, most particularly halo, halo alkyl and hydroxy tamoxifen derivatives, wherein with the native tamoxifen molecule includes a substituted chemical group positioned on the aliphatic chain of the tamoxifen molecule. Particular halogenated tamoxifen derivatives of the invention include chloro, bromo, iodo and fluoro tamoxifen derivatives, and corresponding lower alkyl halogenated forms. The halogenated tamoxifen derivatives possess superior binding affinities for estrogen receptor rich tissues, such as uterine tissue and breast tissue, relative to unsubstituted native tamoxifen. In particular, the fluoro and bromo tamoxifen derivatives have potential use in imaging estrogen receptors by PET whereas the iodinated tamoxifens have potential use in imaging estrogen receptors by SPECT. The bromomethyl tamoxifen derivatives are demonstrated to bind estrogen receptors with the greatest enhancement of binding affinity over native tamoxifen. Rapid and efficient methods of preparing the tamoxifen derivatives having high specific activity (&gt; 6 Ci/<math>\mu</math>mol) are also disclosed. Aliphatic chain substituted tamoxifen derivatives are shown to possess greater estrogen receptor binding affinity and more potent tumor cell inhibition than tamoxifen or tamoxifen derivatives substituted at other locations on the molecule (i.e., non-aliphatic chain substituted tamoxifen). The tamoxifen derivatives of the present invention may advantageously be used as anticancer therapeutic agents to halt estrogen-receptor positive tumors, such as those of breast and uterine tissue.</p>		

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+ DESIGNATIONS OF "SU"

Any designation of "SU" has effect in the Russian Federation. It is not yet known whether any such designation has effect in other States of the former Soviet Union.

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**HIGH AFFINITY TAMOXIFEN DERIVATIVES  
AND USES THEREOF**

The present invention relates to the field of tamoxifen derivatives and analogs, particularly halogenated tamoxifen derivatives and analogs. In that novel tamoxifen derivatives are described wherein the  
5 aliphatic chain of the molecule is substituted with a halogen group, the present invention also relates to methods of synthesizing tamoxifen analogs and derivatives.

10 In that the described tamoxifen derivatives have high affinity for binding estrogen receptors and may be labeled with detectable "tagging" molecules, rendering labeled estrogen receptors highly visible through  
15 positron emission topography (PET) and single photon emission computed tomography (SPECT), the present invention also relates to reagents, radiopharmaceuticals and techniques in the field of molecular imaging.

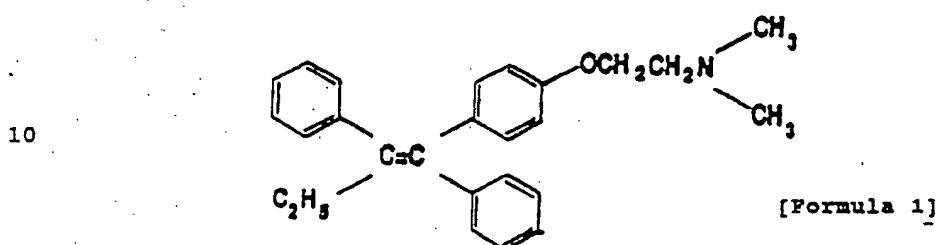
The halogenated tamoxifen derivatives of the present  
20 invention are advantageously used in the imaging of estrogen receptors, for example, in breast, ovarian, uterine and brain tissue and may therefore be useful in the diagnosis of estrogen-receptor positive cancers.

25 The present invention also relates to the field of anti-cancer therapeutic agents, particularly to methods of breast tumor therapy, in that the described high affinity of these halogenated (i.e., iodo-, fluoro-, bromo- and chloro-) tamoxifen derivatives for estrogen  
30 receptors may be advantageously used to treat estrogen-receptor positive tumors.

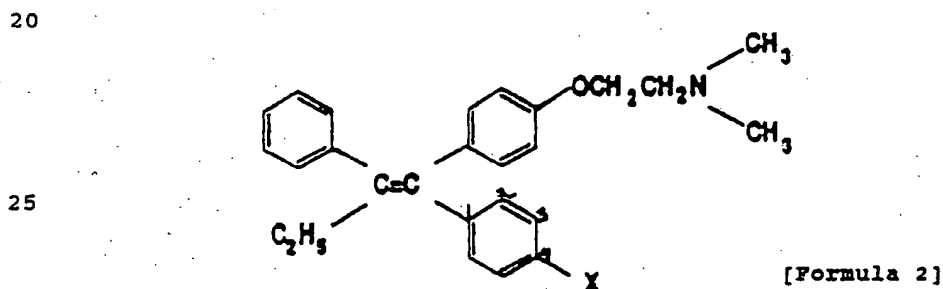
Endocrine therapy provides an important nonsurgical method for treatment for breast carcinoma. This type of therapy is still considered standard for certain subsets of patients, typically postmenopausal women whose primary tumors have high estrogen levels.<sup>1-3</sup> The synthesis of F-18 fluoroestradiol for application in diagnosing breast tumors in humans has recently been described.<sup>4</sup> Observation of significant changes in the binding of estrogen receptors in breast tumors were reported using PET. However, technical difficulties associated with estrogen receptor saturation in patients receiving tamoxifen, or other estrogen receptor antagonist, has been observed to decrease the sensitivity and accuracy of using an estrogen-based receptor tag in diagnosing and monitoring the progress of tumors in patients receiving such treatments.

Tamoxifen (I), a potent non-steroidal antiestrogen, has been widely used in the treatment of human breast tumors. Tamoxifen has few side effects when compared with other hormonal treatments. Tamoxifen is cytostatic (i.e, it prevents/inhibits cell growth), and exerts competitive inhibitory activity at the receptor level with estrogen. More specifically, the cytostatic activity of tamoxifen results from its ability to bind to cytoplasmic estrogen receptors and be translocated to cell nuclei, where cell proliferation is prevented.<sup>1-3</sup> Thus, tamoxifen is often administered as an anticancer agent.<sup>6</sup> For example, Foster et al.<sup>6</sup> describes the effect of various tamoxifen hydroxy-derivatives on the growth of MCF-7 breast cancer cell line in its native form. However, highly active in vitro hydroxy tamoxifen derivatives were found to be less active than tamoxifen in vivo against a DMBA-induced ER-positive tumor in rats and only slightly more active against a hormone dependent mammary tumor in mice.

Tamoxifen has a relatively low binding affinity for the estrogen receptor (ER). Attempts have therefore been made to synthesize tamoxifen derivatives having improved ER binding affinity and specificity to enhance its action as an anti-cancer therapeutic agent. The structure of tamoxifen is demonstrated as:



A variety of modified tamoxifen derivatives have been described in the literature. Structural modifications have been made at virtually every site on the three aromatic rings of the tamoxifen molecule. For example, a 4-hydroxytamoxifen derivative in which X = -OH has been developed having the structure shown below <sup>33</sup>:



However, while the 4-hydroxytamoxifen derivative was shown to be a potent anti-estrogen *in vitro*, it proved to be less effective than tamoxifen *in vivo*, owing to rapid glucuronidation of the hydroxyl group, followed by excretion. 4-Hydroxytamoxifen is the active intracellular form of the tamoxifen molecule *in vivo*, due to cytoplasmic hydroxylation after tamoxifen enters the cell. However, when 4-hydroxytamoxifen is administered

in vivo, its polarity reduces its ability to cross the cell membrane, thereby reducing its access to estrogen receptors located in the cytoplasm. Therefore, in vivo tests indicate 4-hydroxytamoxifen to be less active than  
5 the native tamoxifen.<sup>23</sup>

Other tamoxifen derivatives having a 4-position substitution of the phenyl ring, in which X is methoxy, methyl, fluoro or chloro, have also been proposed and  
10 evaluated.<sup>15</sup> K. E. Allen et al. (1980) conducted studies wherein the 4-methyl, 4-chloro and 4-fluoro derivatives were evaluated and found to have approximately equal activity for estrogen receptor binding affinity compared to tamoxifen in vitro. However, uterine weight tests  
15 indicated that these phenyl group derivatives had lower anti-estrogenic activity than tamoxifen, while other tests indicated that the activity of the 4-methoxy phenyl derivative was about the same as native tamoxifen.

20 A 4-iodo substitution of the phenyl ring as a tamoxifen derivative (formula 2: X = iodo) has recently been found to have greater potency than tamoxifen in relation to detecting estrogen receptor-positive breast cancer.<sup>13</sup> Other 3-iodo, 4-iodo, 3-bromo and 4-bromo  
25 phenyl ring-substituted tamoxifen derivatives have also been described.<sup>13</sup> For example, the McCague et al. patent (U.S. 4,839,155) described the preparation of an iodo or bromo halogenated tamoxifen. However, the halogen, I or Br, was again substituted at one of the phenyl rings of  
30 the tamoxifen structure.

Derivatives of tamoxifen wherein other than the phenyl groups of the molecule are substituted have not been proposed in the art. Such a molecule would be  
35 desirable, as it would leave the major portion of the molecule unchanged and free to bind with the "target"

molecule or tissue cells. Additionally, to further enhance tissue targeting specificity, a non-phenyl ring halogenated tamoxifen derivative would preferably be coupled with a "targeting" molecule, such as a microparticle.

Non-phenyl ring halogenated tamoxifen derivatives with enhanced binding affinity, greater specific radioactivity, and which can readily traverse the cell membrane have not as yet been developed in the art. The development of such derivatives would represent a tremendous improvement in the quality of imaging techniques currently available, as well as improve the accuracy of PET and SPECT scans.

Other alternative compounds proposed as possible radiopharmaceuticals useful in the imaging of tissue receptors include labeled progesterone and estrogen derivatives. For example, Pomper et al. described a ligand for the progesterone receptor.<sup>16</sup> The aliphatic fluorination of FENP (21-[<sup>18</sup>F]fluoro-16- $\alpha$ -ethyl-19-norprogesterone) is described as demonstrating a high specific uterine target tissue uptake.<sup>16</sup> This ligand for the progesterone receptor was labeled with the positron-emitting radionuclide fluorine-18 ( $t_{1/2} = 110$  min).

Estrogen-based imaging agents described in the literature include radionuclides of iodine<sup>20</sup>, fluorine<sup>19</sup>, and bromine<sup>21</sup>. By way of example, an estrogen-based imaging agent described in the literature is the 16- $\alpha$ -[<sup>18</sup>F]fluoro-17- $\beta$ -estradiol ligand.<sup>17</sup>

The preparation of 16- $\alpha$ -[<sup>18</sup>F]fluoroestrogens and their selective uptake by estrogen target tissues in rats has been described by Kiesewetter et al.<sup>19</sup>. Significant changes in the binding of estrogen receptors



in breast tumor were reported with the use of [ $^{18}\text{F}$ ]fluoroestradiol using PET.<sup>4</sup> However, the radioisotope  $^{18}\text{F}$  has a very short half life, and therefore techniques and molecules which employ this radioisotope must be rapid, and preferably more rapid than currently employed molecular labeling techniques allow.

Unfortunately, estrogen-based imaging agents are of limited utility in patients receiving estrogen based therapies due to the competition between imaging agents and therapeutic agents for estrogen receptors. Thus, a poor correlation is likely to exist between the actual physiological response within the tumor during hormonal therapy versus the response which is shown by an estrogen-based imaging agent. For these reasons, a progestin-based imaging agent for breast tumors might be preferred over an estrogen-based agent because tumor response to hormonal therapy appears to correlate better with progesterone receptor positivity than with estrogen receptor positivity.<sup>17</sup> It has further been reported that estrogen receptor positive tumors in patients on hormonal therapy (e.g. tamoxifen) could not be imaged with an estrogen, as the circulating levels of tamoxifen and its metabolites are sufficiently high to fully occupy the estrogen receptor<sup>18</sup>, making visualization quite difficult.

While the radiolabeled tamoxifen derivatives described in the literature have demonstrated some increase in estrogen receptor binding affinity, they do not demonstrate sufficient specific radioactivity due to the low tamoxifen phenolic ring incorporation of the radioactive halogen atoms. Thus, the derivatives' enhanced affinity for estrogen receptor is offset by a reduction in the radioactivity incorporated.

Moreover, the fluorine ion radioisotope,  $^{18}\text{F}$ , with its reportedly low effective dose equivalency and a short half-life ( $t_{1/2} = 110$  min) further exacerbates the problem of obtaining sufficiently labeled reagent, which is  
5 stable over an experimentally useful period of time.

For these reasons, any method which would utilize  $^{18}\text{F}$  in labeling the phenyl rings of tamoxifen molecule must be rapid (i.e. within a 2 hour reaction time) to avoid a  
10 loss in specific activity of the label.

Currently used tamoxifen derivatives, substituted at the various phenolic sites of the tamoxifen structure, can potentially block the formation of the active  
15 metabolite, 4-hydroxytamoxifen. Such a blockage may result in a decrease in receptor binding affinity of the particular tamoxifen analog since the 4-hydroxylated derivative is known to possess higher affinity. Alternatively, a competitive elimination reaction of 4-  
20 position substituted analogs may occur in the cytosol through the formation of the active metabolite, 4-hydroxytamoxifen. Such elimination processes are known to sometimes occur after drugs cross cell membranes.

25 Tamoxifen derivatives which could be more rapidly synthesized, with higher specific radioactivity and/or with improved receptor binding affinity or specificity, would offer a significant advance to the art, especially with regard to the *in vivo* diagnosis and therapy of  
30 estrogen positive tumors and the imaging of estrogen receptors in patients on a hormone-based regimen.

The present invention provides novel halogenated tamoxifen analogs found to have surprisingly and  
35 unexpectedly enhanced binding affinity for estrogen receptors. The particular chemistry of the claimed

tamoxifen analogs and derivatives advantageously provides a rapid and simple method for preparing and labeling the tamoxifen molecule at a non-aromatic carbon of tamoxifen, particularly at the aliphatic (alkyl) chain of the native  
5 tamoxifen structure demonstrated at Formula 1.

The claimed no-carrier added, aliphatic chain substituted and radiolabeled tamoxifen derivatives are unlike any other labeled tamoxifen derivative described  
10 in the literature<sup>13</sup>, and possess an enhanced binding affinity for estrogen receptors while retaining high specific radioactivity. Due to this enhanced binding affinity for estrogen receptors, the described tamoxifen derivatives and analogs can be advantageously employed to  
15 treat, diagnose and/or monitor estrogen receptor-positive tumors (e.g., hormone dependent cancers). Additionally, the derivatives may also be advantageously used to predict the efficiency of tamoxifen-related therapy of breast tumors.

20 The term "aliphatic chain" substituted tamoxifen derivative as used in describing the claimed halogen substituted forms of the native tamoxifen molecule refers to chemically substituted forms of the tamoxifen molecule  
25 wherein a halogen, haloalkyl or hydroxy group is positioned at other than one of the three phenyl rings of the native tamoxifen structure, and at other than the double carbon bond of the native tamoxifen chemical structure (See Formula 1). Even more particularly, the  
30 tamoxifen derivatives of the present invention are defined as including a halogen, haloalkyl or hydroxy group at the end of the aliphatic carbon chain which is pendant to one of the carbons which comprises the double carbon-carbon bond of the native tamoxifen structure.

35

Any of the family of halogen atoms may be used in conjunction with the claimed invention. By way of example, the halogen atoms include fluorine, bromine, iodine, chlorine and astatine. Those particular halogens  
5 most preferred in the present invention include fluorine, bromine, iodine and chlorine.

Applicants' halo-alkyl, halogen and hydroxy substituted tamoxifen derivatives include the halogen  
10 atom or hydroxy moiety strategically placed on the aliphatic chain of the tamoxifen molecule. Thus modified, the molecule has greater estrogen receptor binding affinity than native tamoxifen. Additionally, the placement of a halogen atom at the aliphatic side  
15 chain, rather than on the aromatic portions of the tamoxifen structure, preserves the major portion of the tamoxifen molecule for binding with estrogen receptors and/or other molecules. Moreover, labeling of the tamoxifen structure at the alkyl site rather than at any  
20 of the structures phenolic rings, requires only minimal alteration of the tamoxifen structure. Limited modification of the tamoxifen structure is desirable because phenyl rings and phenoxyethylamine chains are essential for retaining the structure necessary to assure  
25 proper conformational fit with estrogen receptors and to facilitate successful entry of the molecule through the cell membrane and into the cytoplasm for *in vivo* use. As used in the present invention, the term "native" tamoxifen refers to that structure of tamoxifen which is  
30 unsubstituted and which corresponds to the chemical structure presented at Formula 1.

The substitution of the N,N-dimethyl group of tamoxifen with an N,N-diethyl group is demonstrated by  
35 applicants to increase estrogen receptor binding with the halogen tamoxifen analog up to 30-fold. The binding

affinity of the described halogenated tamoxifen derivatives to estrogen receptors is increased in all cases by at least 4-fold as compared to native tamoxifen.

5 Radiolabeling of the halogen tamoxifen derivative with [ $^{18}\text{F}$ ], [ $^{131}\text{I}$ ], [ $^{123}\text{I}$ ], [ $^{77}\text{Br}$ ] for Spect, or [ $^{75}\text{Br}$ ] for PET provides a molecule with both high specific radioactivity and high estrogen receptor binding affinity. Radiolabeled forms of the halogen chloride  
10 [Cl] may also be employed. In order to account for the short half life of the particular radioisotopes used, the Inventors have optimized the synthesis of these halogenated tamoxifen derivatives to provide relatively high specific radioactivity. These halogenated  
15 derivatives are also shown to have high binding affinity for estrogen receptors. The optimization of isotope half life, high estrogen receptor affinity and target cell specificity provides particular advantages for the in vivo imaging of estrogen receptors.

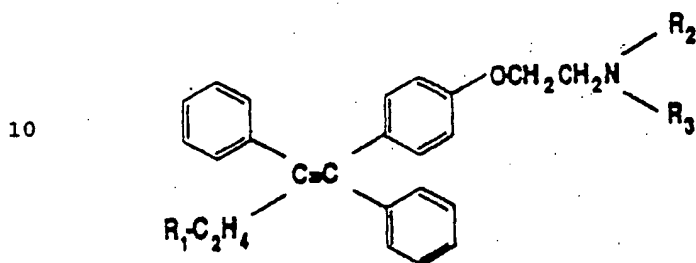
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The distinguishing structural features of the claimed aliphatic chain substituted tamoxifen derivatives establish in part the superiority of the claimed analogs over the N,N-dimethyl (phenyl ring substituted) tamoxifen  
25 derivatives described by Foster et al. and others.<sup>6</sup> The claimed tamoxifen analogs and derivatives also feature the specific substitution of tamoxifen with a fluorine, iodine, chlorine or bromine halogen atom or lower halo-alkyl group at the aliphatic chain of the tamoxifen  
30 molecule, in contrast to the phenyl-ring substituted tamoxifen structure described in Foster et al.<sup>6</sup> The synthesis and chemical structure of the claimed halogenated and halo-alkyl tamoxifen analogs are distinct from all derivatives discussed in the literature,

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including the phenolic ring-substituted tamoxifen derivative described by McCague in U.S. Patent No. 4,839,155.

5 Most generally, the tamoxifen derivatives of the claimed invention comprise the following structure:



wherein  $R_1$  is a halogen or lower halo-alkyl; chloromethyl, bromomethyl-hydroxy, hydroxymethyl, tosyl or tosylmethyl;  $R_2$  is a lower alkyl;  $R_3$  is a lower alkyl, and wherein  $R_2$  is not methyl when  $R_3$  is methyl. In a most preferred embodiment of the described tamoxifen derivatives,  $R_2$  and  $R_3$  are most particularly defined as ethyl. In still another embodiment,  $R_2$  is methyl and  $R_3$  is ethyl. In particular embodiments of the invention,  $R_1$  is fluoromethyl and  $R_2$  and  $R_3$  are ethyl. In still another embodiment,  $R_1$  is iodomethyl and  $R_2$  and  $R_3$  are ethyl.

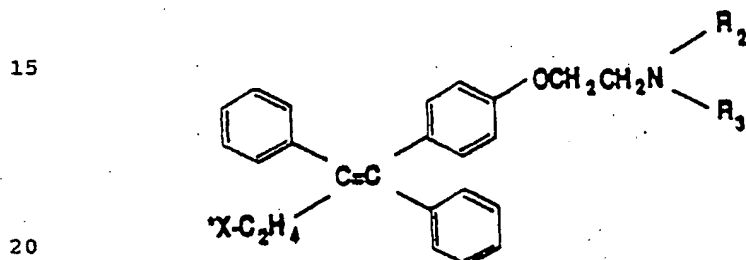
A lower halo-alkyl as defined for purposes of the present invention is a carbon chain of less than 5 carbons with a halogen atom attached thereto. A lower alkyl is defined as a carbon chain of less than 5 carbon atoms such as methyl (1-C), ethyl (2-C), propyl (3-C), butyl (4-C) or pentyl (5-C). Most preferably  $R_2$  is methyl or ethyl. Similarly,  $R_3$  is most preferably methyl or ethyl. However,  $R_2$  is not methyl when  $R_3$  is methyl.

35

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In a particularly preferred embodiment of the tamoxifen derivatives described herein,  $R_1$  is a halogen further defined as bromine, chlorine, fluorine or iodine. Where  $R_1$  is a lower halo-alkyl, the lower halo-alkyl by way of example is defined as bromomethyl, fluoromethyl, iodomethyl or chloromethyl. In still a further embodiment of the described tamoxifen derivative,  $R_1$  is a lower hydroxy alkyl, such as, for example, hydroxymethyl.

In a second most particularly preferred embodiment, the tamoxifen derivatives included within the scope of the invention are radiolabeled, and comprise:



wherein  $X$  is  $^{18}\text{F}$ ,  $^{131}\text{I}$ , [ $^{18}\text{F}$ ]fluoromethyl, [ $^{131}\text{I}$ ]iodomethyl, chloromethyl, or bromomethyl;  $R_2$  is methyl or ethyl, and wherein  $R_3$  is methyl or ethyl. Most preferably,  $R_2$  is not methyl when  $R_3$  is methyl. In a particularly preferred embodiment of this particular tamoxifen derivative,  $X$  is [ $^{18}\text{F}$ ]fluoromethyl,  $R_2$  is ethyl, and  $R_3$  is ethyl. The three phenyl rings of the tamoxifen structure are unsubstituted phenyl rings. In still another particularly preferred embodiment,  $X$  is [ $^{131}\text{I}$ ]iodomethyl,  $R_2$  is ethyl and  $R_3$  is ethyl.

In still another most preferred embodiment of the claimed tamoxifen derivative,  $R_1$  is chloromethyl or chloro,  $R_2$  is ethyl and  $R_3$  is ethyl. Where bromine is the

halogen,  $R_1$  is bromomethyl or bromo,  $R_2$  is ethyl and  $R_3$  is ethyl.

The fluoromethyl tamoxifen derivatives herein  
5 disclosed demonstrate an enhanced binding affinity for  
estrogen receptors compared to other tamoxifen  
derivatives having a a 30-fold (*trans*) and 6-fold (*cis*)  
enhanced estrogen receptor binding affinity. For iodo-  
methyl tamoxifen analogs, the *trans* isomer has a 15-fold  
10 and the *cis*-isomer has a 10-fold enhanced estrogen  
receptor binding affinity, compared to other tamoxifen  
derivatives described in the literature. Salituro et al.  
reported that the *cis* isomer of tamoxifen azizidine has  
50-fold less affinity than the *trans* isomer. Placing a  
15 fluorine atom at the 4-position of phenyl ring has been  
demonstrated to decrease binding affinity 40-fold when  
compared to native tamoxifen. Pomper et al describes  
progesterone analogs only, which have affinity for  
progesterone receptors. Thus, that data is not directly  
20 compared here. (Shani et al.)<sup>38</sup>

The bromomethyl tamoxifen analogs provide for the  
*trans* isomer a 50-fold enhancement of estrogen receptor  
binding affinity, and for the *cis* isomer, a 38-fold  
25 enhancement of estrogen receptor binding affinity.  
Particular other of the tamoxifen derivatives exhibit at  
least a 4-fold increase in estrogen receptor binding  
affinity compared to native tamoxifen.

30 Because of the enhanced estrogen receptor binding  
affinity demonstrated by the described tamoxifen  
derivatives and analogues, Applicants provide an  
efficient and specific reagent which is useful in the  
imaging of estrogen receptors. In such an embodiment,  
35 the tamoxifen derivative includes a radiolabel "tag",  
most preferably an  $^{18}\text{F}$ ,  $^{131}\text{I}$ ,  $^{123}\text{I}$  or  $^{75}\text{Br}$  (for positron)



and  $^{77}\text{Br}$  atom (for SPECT). In a most particularly preferred embodiment of the imaging reagent, the "tag" is an  $^{18}\text{F}$ ,  $^{131}\text{I}$ , or  $^{77}\text{Br}$  radionucleotide located at the alkyl side chain of the halogen-substituted tamoxifen molecule.

5

Most preferably, the alkyl side chain (for  $\text{R}_2$  and  $\text{R}_3$ ) comprises a carbon chain of at least two carbons (ethyl). Methods of performing the described radiosynthesis of the disclosed [ $^{18}\text{F}$ ]fluoromethyl, [ $^{131}\text{I}$ ]iodomethyl,  $^{77}\text{Br}$  bromomethyl tamoxifen derivatives are also provided  
10 herein. The radiosynthesis of  $^{77}\text{Br}$ -labeled tamoxifen is similar to the  $^{131}\text{I}$ -labeled analog. Therefore, the methods described herein for the preparation of radiolabeled fluoro and iodo tamoxifen derivatives may be  
15 utilized for the preparation of radiolabeled forms of the bromo and chloro derivatives, by using an analogous bromo- or chloro-salt as the starting reagent.

In that the halogenated derivatives of tamoxifen  
20 disclosed herein have enhanced estrogen receptor binding affinity, the presently disclosed tamoxifen derivatives provide an improved method by which estrogen receptors may be imaged through a PET or a SPECT radioimaging protocol. Most particularly, the halogen to be used in  
25 forming these estrogen binding agents is fluorine, bromine, or iodine.

Additionally, in order to even further enhance the tissue- targeting of the halogen tamoxifen derivatives to  
30 those tissues rich in estrogen receptors, the Inventors propose to couple the described radiolabeled, substituted tamoxifen derivatives to microparticles. This coupling can be accomplished by reacting the halogenated tamoxifen with a polymer in the presence of a coupling reagent  
35 (e.g., dicyclohexylcarbodiimide) (See Figure 4). The coupling of the tamoxifen derivative with the

microparticle is expected to enhance the molecule targeting to particular tissues. The "payload" (e.g., a chemotherapeutic halogenated tamoxifen derivative) can then be released from microparticles by a diffusion or erosion process and used to kill tumors.

To test this approach, estrone (estrogen agonist) was conjugated to poly(benzyl)glutamate (PBLG). After conjugation, the estrogen receptor binding was determined. The  $IC_{50}$  for estrone was  $5 \times 10^{-8} M$ , whereas the conjugated analog was  $5 \times 10^{-7} M$ . The conjugation yield was 86% (determined from UV at 282 nm). PBLG polymer loaded with cisplatin (an antitumor agent) showed sustained release properties (particle size 100  $\mu M$ ). Similar conjugation techniques will be used to conjugate halogenated tamoxifen to PBLG.

Any substituted tamoxifen derivative, wherein the halogen substitution is located at a non-aromatic site of the tamoxifen molecule, specifically at the aliphatic side chain (i.e., the  $C_2H_5$  group shown in the native tamoxifen structure), would be capable of functioning as an imaging agent with enhanced estrogen receptor binding affinity. The halogenated tamoxifen derivatives most preferred in the present invention include the bromotamoxifen analogs, such as bromomethyltamoxifen. Of the fluoromethyl derivatives, N-diethylfluoromethyltamoxifen is most preferred. The most preferred iodotamoxifen derivative of the described estrogen receptor radiopharmaceutical agents is iodomethyltamoxifen labeled with  $^{131}I$ . The most preferred bromotamoxifen derivatives of the present invention include the bromomethyltamoxifen analogs labeled with  $^{77}Br$ .

One object of the present invention is to provide an estrogen receptor imaging reagent which has high affinity

for the estrogen receptor and high enough specific activity ( $>1$  ci/ $\mu$ mol) to be suitable for use in positron emission tomography. Another object of the invention is to provide an imaging reagent which, as a result of the foregoing characteristics, has superior target tissue selectivity in vivo. Another object of the present invention is to provide a method for monitoring the effectiveness of tamoxifen therapy in treating breast tumors.

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A further object of the present invention is to achieve a substituted tamoxifen derivative which has both high estrogen receptor binding affinity and high specific radioactivity. More specifically, an object of the present invention is to provide an easy and rapid radiosynthesis of substituted tamoxifen derivative (i.e., with fluoro-, iodo-, chloro-, or bromo- or hydroxy-tamoxifen analogs) with high specific radioactivity (e.g.,  $^{18}\text{F}$ ,  $^{131}\text{I}$ , or  $^{77}\text{Br}$ ) at the aliphatic chain of the tamoxifen structure.

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By providing a molecular substitution (i.e., halogen, halo alkyl or hydroxy group) at the aliphatic chain of the tamoxifen molecule, the bioactivity of the claimed tamoxifen derivatives is preserved through the retention of the majority of the native structure of the molecule, leaving the majority of the molecule available for binding cell (estrogen) receptors.

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An additional object of the invention is to provide a simple and inexpensive method for radiosynthesizing these derivatives.

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Methods for preparing the disclosed site specific halogenated tamoxifen derivatives are thus also provided. Currently available methods for directing the

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substitution of tamoxifen at the aliphatic chain require multiple and time consuming chemical steps. Thus, the formulation of a more efficient and rapid method for preparing halogen alkyl chain substituted tamoxifen derivatives would represent a significant and valuable advance in using particular short half life radiolabeled tamoxifen analogs as radiopharmaceuticals. For example, radionuclide  $^{18}\text{F}$  analogs have an extremely short half life of only about 2 hours. Therefore, time is of the essence in processing and using  $^{18}\text{F}$ -labeled tamoxifen analog molecules.

An additional object of the present invention is to provide halogenated tamoxifen derivatives which have superior estrogen receptor binding affinities compared to native tamoxifen and to the tamoxifen and progestin derivatives described in the literature.

By way of example, such halogen tamoxifen derivatives of the present invention include fluoro-, iodo-, bromo- and chloro- tamoxifen analogs. In regard to the  $\text{IC}_{50}$  values, it should be considered that different species (e.g., pig, rat, dog, rabbit) will have different  $\text{IC}_{50}$  values (for the same compound). However, the  $\text{K}_i$  should remain the same. Therefore, to report data, one must include a standard sample (e.g., tamoxifen, estradiol, diethylstilbestrol) and compare the relative value to a standard sample.  $\text{IC}_{50}$  values, therefore, between species cannot be readily compared. Relative binding affinities are more easily comparable. Results of the presently described halogenated alkyl analogs of tamoxifen are therefore expressed in terms of relative binding affinities.

Another object of the present invention is to provide a more stable in vivo reagent. The Inventors

have discovered that one of the advantages of adding halogen atoms to the tamoxifen alkyl chain, instead of at a ring structure of the molecule, is that the molecule has a greater *in vivo* stability. For example, the active metabolite of tamoxifen is formed at the 4-position of the aromatic ring. If a halogen is placed on the phenyl ring, the halogen-substituted site of the molecule will hinder active metabolite formation. Also, *in vivo* elimination of halogen may then occur at the phenyl ring to destroy the halogen-substituted forms of tamoxifen. Thus, halogen substitution on the phenyl ring reduces the amount of active metabolite formation *in vivo*. Substitution of the tamoxifen molecule at the alkyl chain, provides a more stable *in vivo* reagent as the alkyl chain portion of the tamoxifen molecule does not block the hydroxylation reaction which results in the formation of the active metabolite of tamoxifen.

An additional object of the invention is to provide an effective anti-cancer therapeutic agent for reducing estrogen-receptor positive breast, ovarian, and uterine cancer. The described analogs may also be useful as anti-cancer agents of cancers affecting the estrogen receptor-rich tissue of the brain.

An ultimate object of the present invention is to provide a non-steroid based radiopharmaceutical agent, useful in PET, which has high specific radioactivity and high target tissue selectivity by virtue of its high affinity for the estrogen receptor. The tissue selectivity is capable of further enhancement by coupling this highly selective radiopharmaceutical with targeting agents, such as microparticles.

These objects of the present invention are served with the particular aliphatic substituted tamoxifen

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derivatives of the present invention. Scatchard analysis of estrogen receptor binding in pig uterus using [H-3]estradiol gave Bmax=376 fmol/mg of protein and Kd=5nM. The IC-50s ( $\mu$ M) were: TX, 30, FMTX, Cis = 5, trans = 1; ClMTX, cis = 4, trans = 0.4; BrMTX, cis = 0.8, trans = 0.2; ImTX, cis = 3, trans = 2; OHMTX cis = 10, trans = 7. For MCF7 breast tumor cell inhibition, the IC-50 of TX was 11  $\mu$ M. The relative potencies were TX = 100; FMTX, cis = 224, trans = 93; ClMTX, cis = 335, trans = 146; BrMTX, cis = 2355, trans = 298; IMTX, cis = 466, trans = 175; OHTX, cis = 66, trans = 50. These results indicate that all of the halogenated analogs of tamoxifen produce greater receptor binding affinity and have more potent tumor cell inhibition than tamoxifen, thus establishing their utility for in vivo imaging of breast tumors.

Additionally, ER binding in pig uterus using [<sup>3</sup>H] estradiol, Scatchard analysis (N=9) gave Kd = 5nM and Bmax = 376 fmol/mg of protein. The Ki (nM) values were: TX = 15,000; fluoromethyl TX (FMTX), cis=2500, trans = 500; iodomethyl - TX (IMTX), cis = 1500, trans = 1,000. In vivo tissue uptakes in rat (% injected dose per organ, n=5) for <sup>131</sup>I-IMTX (trans) at 3h, 6h, and 24h were: uterus, 0.5  $\pm$  0.04, 0.14  $\pm$  0.16 and 0.01  $\pm$  0.001; liver, 5.3  $\pm$  0.84, 3.0  $\pm$  0.02, 1.7  $\pm$  0.21. Uterus/blood ratios were 1.6, 1.5 and 1.2. The IC50 ( $\mu$ M) values for MCF7 cell inhibition were TX = 11, FMTX, cis = 4.5, trans = 1.8, IMTX, cis = 2.4, trans = 6.3 uterus/muscle ratios were 11.0, 7.6 and 3.6.

The following numerical designation of particular tamoxifen compounds is employed throughout the Specification:

	Compound I	-	Tamoxifen
	Compound II	-	N,N-diethyl-hydroxytamoxifen
	Compound III	-	N,N-diethyl-hydroxymethyltamoxifen
	Compound IV	-	N,N-diethyl-fluorotamoxifen
5	Compound V	-	Hydroxytamoxifen
	Compound VI	-	N,N-diethyl-fluoromethyltamoxifen
	Compound VII	-	Fluorotamoxifen
	Compound VIII	-	N,N-diethyl-O-tosyltamoxifen
	Compound IX	-	N,N-dimethyl-O-tosylmethyltamoxifen
10	Compound X	-	N,N-diethyl-iodomethyltamoxifen
	Compound XI	-	N,N-diethyl-bromomethyltamoxifen
	Compound XII	-	N,N-diethyl-chloromethyltamoxifen

15 The following abbreviations are included throughout the body of the Specification:

	BrTX	=	bromotamoxifen
	BrMTX	=	bromomethyltamoxifen
	ClTX	=	chlorotamoxifen
	ClMTX	=	chloromethyltamoxifen
20	ITX	=	iodotamoxifen
	IMTX	=	iodomethyltamoxifen
	FTX	=	fluorotamoxifen (VII)
	FMTX	=	fluoromethyltamoxifen
	TX	=	tamoxifen (I)
25	$B_{max}$	=	the total number of binding sites determined from Scatchard analysis.
	$E_2$	=	estradiol
30	$IC_{50}$	=	the concentration of test compounds that decreases 50% of specific radioligand binding in receptor assay or 50% of cell viability in MCF-7 cell growth assay.
	PET	=	positron emission topography
35	$K_d$	=	dissociation constant determined from a saturation estrogen receptor assay and a Scatchard analysis.

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ER = estrogen receptor  
FMTX = Fluoromethyltamoxifen  
K<sub>i</sub> = inhibition constant determined using the  
equation

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$$K_i = \frac{IC_{50}}{1 + [^3H] \text{ estradiol}/K_d}$$

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RBA = relative binding affinity,  
the relative concentration  
of estradiol and tamoxifen  
or its derivatives required  
to achieve 50% inhibition  
of [<sup>3</sup>H]-E<sub>2</sub> binding.

15

RP = relative potency  
TX = Tamoxifen

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Figure 1 - Synthesis of Tamoxifen Derivatives.

Figure 2 - Estrogen receptor saturation  
experiment measuring findings in pig  
uterus *in vitro*. This is to  
determine the nature of estradiol  
interaction with the estrogen  
receptor site.

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Figure 3 - Estrogen receptor Scatchard plot  
analysis. This is to demonstrate  
that estradiol has competitive  
reversible binding. The receptor  
density of pig uterus and affinity  
constant (K<sub>d</sub>) were determined.

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Figure 4 - Diagram of the coupling reaction  
between estrone (or tamoxifen) and  
polyglutamate (PGLA).

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Figure 5 - HPLC Chromatogram of (trans)  
fluorotamoxifen.

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Figure 6 - (cis) fluorotamoxifen Scatchard plot  
analysis.

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Figure 7 - (trans) fluorotamoxifen Scatchard  
plot analysis. Notice the presence



of the ab "quartet". This quartet is only found in the trans isomer.

5        Figure 8 -        (trans) iodotamoxifen Scatchard plot analysis. Notice the presence of ab "quartet".

10       Figure 9 -        (trans) bromotamoxifen. Scatchard plot analysis. Notice the presence of the ab "quartet".

15       Figure 10 -       (trans) bromotamoxifen. Scatchard plot analysis. Notice the presence of the ab "quartet".

The present invention discloses aliphatic chain-substituted tamoxifen derivatives having markedly enhanced estrogen receptor binding affinity compared to native forms of tamoxifen. The tamoxifen derivatives may include a halogen, a hydroxy or a lower haloalkyl moiety. Any of the halogen molecules Br, Cl, I, or F may be employed in the described site-specific halo and haloalkyl tamoxifen derivatives. Particularly preferred halotamoxifen derivatives of the present invention include fluorotamoxifen (FTX), iodotamoxifen (ITX), bromotamoxifen (BrTX), and chlorotamoxifen (ClTX) iodomethyltamoxifen (IMTX). By way of example, these lower haloalkyltamoxifen derivatives include cloromethyl tamoxifen (ClMTX).

The present invention also includes radiolabeled forms of tamoxifen. The radiolabeled forms of the substituted tamoxifen derivatives provide reagents having high specific activity. These radiolabeled tamoxifen derivatives are demonstrated to be particularly useful in estrogen receptor mapping in estrogen rich tissues, such as the uterus and breast.

40       Unlabeled forms of the described fluorotamoxifen derivatives were prepared from hydroxytamoxifen via

diethylaminosulfur trifluoride reaction at a 47% product yield. The binding affinity of these particularly synthesized fluorotamoxifen derivatives to cytosol estrogen receptors of pig uteri *in vitro* was higher ( $K_i$  is 500 nM; *trans*-compound VI) than the binding affinity observed between estrogen receptors and native tamoxifen ( $K_i$  is 15,000 nM).

Unlabeled forms of iodomethyltamoxifen were prepared from tosyl analogs of tamoxifen by reacting with sodium iodide. The binding affinity of iodotamoxifen was 10-15 fold higher than tamoxifen. The unlabeled forms of chloromethyltamoxifen or bromomethyltamoxifen were prepared by treatment of a tamoxifen hydroxy precursor with  $\text{SOCl}_2$  or  $\text{CBr}_4$ , respectively, to provide chloromethyltamoxifen and bromomethyltamoxifen in 87% and 50% yields, respectively.

Radiosynthesis with fluorine-18 was performed on tosyl tamoxifen analogs to produce radiolabeled fluorotamoxifen molecules having the described high specific activity (2-4 Ci/ $\mu\text{mol}$ ) and a radiochemical yield of 60%. Radiochemical purity was > 99%. Radiosynthesis of  $^{131}\text{I}$ -labeled analogs (Compound X) of tamoxifen was performed by reacting tosyl analogs of tamoxifen with NaI. The radiochemical yield was 60%.

The fluoromethyl tamoxifen, chloromethyl tamoxifen, bromomethyl tamoxifen and iodomethyltamoxifen analogs were found to bind to cytosol estrogen receptors of pig uteri and ovaries. IC-50's ( $\mu\text{M}$ ) for F, Cl, Br, I, and native tamoxifen (TX) were found to be 1, 0.4, 0.2, 2 and 30. These results demonstrate that these halogenated derivatives are effective competitive ligands of [ $^3\text{H}$ ]estradiol (5 nM).

Clomiphene, estradiol, and tamoxifen were obtained from Sigma Chemical Company (St. Louis, MO). Flash chromatography according to the procedure of Still et al.<sup>7</sup> was used. Silica gel Sep-Paks from Waters Associates (Milford, MA) were used for purifications. Thin-layer chromatographic (TLC) analysis was performed on Whatman K6F silica gel-packed plates (250  $\mu$ m) (Anspec, MI). [<sup>3</sup>H]estradiol (specific activity 160 Ci/mmol) for receptor binding was purchased from Amersham (Arlington Heights, IL). The no-carrier-added Na<sup>131</sup>I was purchased from Syncore. High pressure liquid chromatography (HPLC) was carried out on a LDC system, consisting of two LDC ConstaMetric Pumps, a Rheodyne injector and a Spectra Physics model SP8450 variable UV/Vis detector.

Melting points were determined on a Meltemp melting point apparatus and are uncorrected. <sup>1</sup>H NMR spectra were obtained from a GE 300 MHz instrument, and mass spectral data were obtained by direct probe analysis (Finnigan MAT INCOS-50) at The University of Texas Health Science Center, Houston, Texas. Elemental analyses were performed by Galbraith Laboratories, Inc., Knoxville, TN.

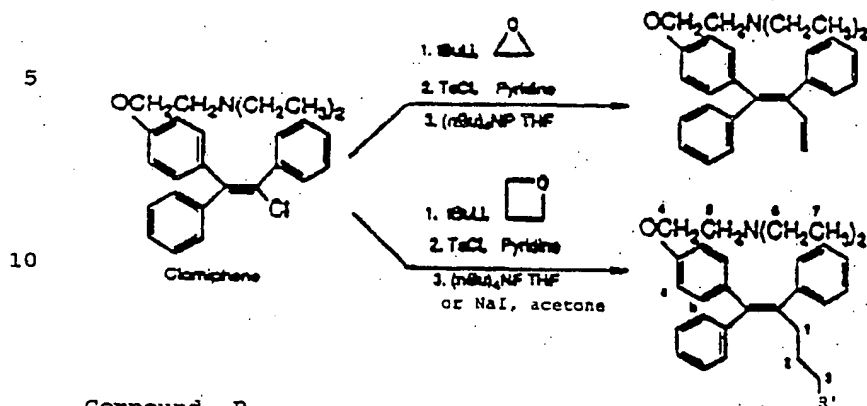
Improved and more efficient methods for the synthesis of all of the described halogenated tamoxifen analogs, including N,N-diethylfluorotamoxifen, fluoromethyl-N,N-diethyltamoxifen, N,N-diethylbromomethyltamoxifen, N,N-diethylchloromethyltamoxifen and iodomethyl-N,N-diethyltamoxifen are also disclosed as part of the invention. For example, the synthesis of fluoromethyltamoxifen and iodotamoxifen (lower alkyl halotamoxifen derivatives) has been simplified from an at least ten (10) step procedure to a more rapid and simple three-step procedure (Figure 1). The N,N-diethylfluoro (Compound IV) and the N,N-diethylfluoromethyl (Compound VI) and N,N-diethyliodomethyl (Compound X) analogs of

tamoxifen were prepared for preliminary evaluation according to these improved protocols. N,N-Diethylfluoro (IV), N,N-diethylfluoromethyl (VI) and N,N-diethyliodomethyl (X) analogues of tamoxifen were prepared from the corresponding hydroxy analogues of tamoxifen via tosyl analogues by displacement with either sodium fluoride or sodium iodide. N,N-diethylbromomethyltamoxifen (XI) and N,N diethylchloromethyltamoxifen (XII) analogs of tamoxifen were prepared from the corresponding hydroxy precursors of tamoxifen with  $\text{CBr}_4$  or  $\text{SOCl}_2$ , respectively. Mixtures of the *cis*- and *trans*-isomers of the respective alkyl-chain substituted tamoxifen derivatives were obtained from this synthesis.

The *cis*- and *trans*- isomer products of each of the reactions described above were separated by passing the reaction mixture through a silica gel-packed column and eluting with ether/petroleum ether/triethylamine (1:1:0.1). The  $^1\text{H}$ NMR chemical shift signals for *cis*- and *trans*-isomers were assigned based on published information.<sup>8,11</sup>

It was ascertained that the tosyl group on N,N-diethyl-O-tosyltamoxifen could be displaced by nucleophilic fluoride substitution reaction with a milder condition (e.g. kryptofix-222 and KF). Using this procedure, the fluoro-analogue of tamoxifen, compound IV, was prepared in 40% yield from the corresponding tosyl derivative of hydroxytamoxifen. However, elimination occurred to form the butadiene by-product in the presence of the stronger base (e.g. tetrabutylammoniumhydroxide). The formation of the butadiene by-product is due to an elimination reaction on the tosyl analogue.

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Synthesis of Aliphatic Halotamoxifen Derivatives

Compound	R
VI	F
X	I

VI	F
X	I

Increasing the side chain by one carbon results in the synthesis of *Cis*-*N,N*-diethylfluoromethyltamoxifen (VI), which is more stable toward tosyl elimination. The yield for compound VI was 60%. Compound VI showed a 6-fold (*cis*) and 30-fold (*trans*) higher affinity for the estradiol receptor binding site than native tamoxifen. The yield for Compound X was 50% (*trans*) and 70% (*cis*). Compound X showed a 10-fold (*cis*) and 15-fold (*trans*) higher ER affinity than tamoxifen. Receptor binding affinity of fluorotamoxifen, with a fluorine atom placed on the phenyl ring of tamoxifen, and of iodotamoxifen, with an iodine atom placed on the phenyl ring of tamoxifen, has been reported.<sup>22, 23</sup> However, that reaction for fluorotamoxifen preparation takes longer and yields lower specific radioactivity for <sup>18</sup>F-labeled tamoxifen, which is not practical for estrogen-receptor studies using PET.

The iodine atom placed on a phenyl ring at the 2-position next to the phenoxy ring gave poor estrogen receptor binding. The iodine atom placed on the 4-position of the aromatic ring gave good receptor binding<sup>13</sup>, yet it may be unstable in vivo due to an elimination reaction, resulting in formation of the active hydroxy metabolite. Also, the iodine atom is quite bulky, and may change the planar conformation (e.g., phenyl ring) impairing the binding to estrogen receptors, thereby decreasing binding affinity.

As used in the present invention, the term "lower alkyl" refers to a carbon chain of less than 5 carbon atoms in length. Most preferably the lower alkyl comprises 1 carbon (methyl) or 2 carbons (ethyl).

The following Examples are presented only to describe preferred embodiments and utilities of the present invention, and to satisfy best mode requirements. The examples are not meant to limit the scope of the present invention unless specifically indicated otherwise in the claims appended hereto.

EXAMPLE 1 - SYNTHESIS OF TRANS-FLUOROTAMOXIFEN  
(COMPOUND VII)

Hydroxytamoxifen (trans) (V) (8) (330 mg, 0.85 mmol) was dissolved in methylene chloride (20 ml), cooled to -40°C and then treated with triethylamine (200 µl) added. Diethylaminosulfur trifluoride (250 µl, 1.89 mmol) was added and the reaction mixture was stirred for 1 hour at -40°C according to our previous published method.<sup>9</sup> The reaction mixture was then washed with water and the methylene chloride layer evaporated to dryness. The reaction mixture was chromatographed on a silica gel

column using 1:1:0.1 hexane/ethylacetate/triethylamine as eluant to yield 145 mg (43.7%) of VII:R<sub>E</sub> 0.40 (1:1:0.1 ether/petroleum ether/triethylamine); <sup>1</sup>HNMR (CDCl<sub>3</sub>) δ 2.29 (s, 6, NMe<sub>2</sub>) 2.66 (t, J= 5.6Hz, 2, OCH<sub>2</sub>CH<sub>2</sub>N), 2.87 (dt, J=21.2 Hz, 6.3Hz, 2, CH<sub>2</sub>CH<sub>2</sub>F), 3.93 (t, J=5.5 Hz, 2, OCH<sub>2</sub>CH<sub>2</sub>N), 4.34 (dt, J= 47.2 Hz, 6.3Hz, 2, CH<sub>2</sub>F), 6.56 (d, J= 8.5Hz, 2, ArH 3,5 to OCH<sub>2</sub>), 6.77 (d, J= 8.3 Hz, 2, ArH 2,6 to OCH<sub>2</sub>), 7.12-7.35 (m, 10, ArH); m/z 389 (12, M<sup>+</sup>), 342 (30, <sup>+</sup>CH<sub>2</sub>-CH<sub>2</sub>-F).

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**EXAMPLE 2 - SYNTHESIS OF N,N-DIETHYLHYDROXYTAMOXIFEN (COMPOUND II)**

Clomiphene (6.06 g, 14.9 mmol) was dissolved in tetrahydrofuran (100 ml) and cooled to -40°C. t-Butyl lithium (1 M in pentane, 24 mmol) was added slowly. After 5 minutes, ethylene oxide (14.6 ml, 290 mmol) was added, and the reaction mixture was stirred for 6 hours, poured into water and extracted with ether. The ether layer was evaporated and chromatographed on a silica gel column using 1:1:0.1 ether/petroleum ether/triethylamine as eluant to yield trans product (1.96 g, 27.1%, oil): and cis product (1.56 g, 21.5%, oil): Assignment of <sup>1</sup>HNMR for aliphatic protons are presented in Table 1.

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**EXAMPLE 3 - SYNTHESIS OF N,N-DIETHYL-O-TOSYLTAMOXIFEN (COMPOUND VIII)**

Cis- or trans- N,N-diethylhydroxytamoxifen (II) (100 mg, 0.27 mmol) was dissolved in methylene chloride (2 ml) and cooled to 0°C. Pyridine (150 µl) and tosyl chloride (55 mg, 0.27 mmol) were added. After 2 hours, the reaction mixture was diluted with methylene chloride and washed with water. The methylene chloride layer was evaporated and chromatographed on a <sup>18</sup>C column using 85:15:1 acetonitrile/water/triethylamine as eluant to yield cis (51 mg, 34%, oil) or trans tosyl analog (30 mg,

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20%, oil):  $m/z$  569(60,  $M^+$ ), 397(20,  $^{+}OSO_2PhCH_3$ ). Values for aliphatic protons are presented in Table 1.

EXAMPLE 4 - SYNTHESIS OF N,N-DIETHYLFLUOROTAMOXIFEN  
(COMPOUND IV)

5

The present example is provided to demonstrate two methods by which compound IV may be prepared.

10 Method 1

*Cis* or *trans* N,N-diethylhydroxytamoxifen (II) (400 mg, 0.96 mmol) was dissolved in tetrahydrofuran (25 ml), and the solution was cooled to  $-40^{\circ}C$ . A solution of triethylamine (480  $\mu$ l) was added. Diethylaminosulfur trifluoride (1280  $\mu$ l, 2.11 mmol) was added and the reaction mixture was stirred for three hours at  $-40^{\circ}C$ . The crude material was poured into water and then extracted with ether. The ether layer was dried over anhydrous magnesium sulfate, filtered and evaporated to dryness. The mother liquor was chromatographed on a silica gel packed (3 x 60 cm, ACE Gloss) column using 1:1:0.1 ether/petroleum ether/triethylamine to yield purified 60 mg (15%) of *trans* IV (oil):  $R_f$  0.70, and 80 mg (20%) of *cis* IV (oil),  $R_f$  0.60 (1:1:0.1 ether/petroleum ether/triethylamine); *trans*  $^1H$ NMR ( $CDCl_3$ )  $\delta$  1.02(t,  $J=7.3$  Hz, 6,  $(CH_3CH_2N)$ , 2.57 (q,  $J=7.1$  Hz, 4,  $CH_3CH_2N$ ), 2.78(t,  $J=6.3$  Hz, 2,  $OCH_2CH_2N$ ), 2.91 (dt,  $J=21.5$  Hz, 6.3 H, 2,  $CH_2CH_2F$ ), 3.90 (t,  $J=6.2$  Hz, 2,  $OCH_2CH_2N$ ), 4.33 (dt,  $J=47.4$  Hz, 6.3 Hz, 2,  $CH_2CH_2F$ ), 6.56 (d,  $J=8.5$  Hz, 2, ArH 3,5 to  $OCH_2$ ), 6.75 (d,  $J=8.7$  Hz, 2, ArH 2,6 to  $OCH_2$ ), 7.12-7.37 (m, 10, ArH);  $m/z$  417(50,  $M^+$ )Hz. Anal. ( $C_{28}H_{32}NOF \cdot 1/3 H_2O$ ) C, H, N. Calc., C:79.40, H:7.70, N:3.31; Found, C:79.71, H:7.61, N:3.36. *cis*  $^1H$ NMR ( $CDCl_3$ )  $\delta$  1.08 (t,  $J=7.1$  Hz, 6,  $CH_3CH_2N$ ), 2.64 (q,  $J=7.3$  Hz, 4,  $CH_3CH_2N$ ), 2.89-2.96 (m, 4,  $OCH_2CH_2N$  and  $CH_2CH_2F$ ), 4.06 (t,  $J=6.4$  Hz, 2,  $OCH_2CH_2F$ ), 4.35(dt,  $J=47.1$  Hz, 6.4 Hz, 2,

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$\text{CH}_2\text{CH}_2\text{F}$ ), 6.89-7.26 (m, 14, ArH);  $m/z$  417 (70,  $\text{M}^+$ ), 402 (30). m.p. 55-57°C Anal. ( $\text{C}_{28}\text{H}_{32}\text{NOF} \cdot 0.5 \text{H}_2\text{O}$ ) C,H,M, calc., C:78.84, H:7.80, N:3.28; Found, C:78.71, H:7.48, N:3.20

## 5 Method 2

N,N-Diethyl tosyl analogue of tamoxifen (VIII) (40 mg, 0.07 mmol) was dissolved in tetrahydrofuran (200  $\mu\text{l}$ ) and then treated with tetrabutylammonium fluoride (170  $\mu\text{l}$ , 1M in tetrahydrofuran). Fifteen minutes after adding  
10 TBAF, two spots were visualized by silica gel TLC (4:1 chloroform/methanol). Both products were isolated from a silica gel Sep-Pak by elution with ether/petroleum ether/triethylamine (1:1:0.1). One product isolated was the trans isomer of compound (IV) (11 mg, 40%) and the  
15 other was a butadiene derivative (30%, oil). Butadiene derivative  $^1\text{H}$ NMR ( $\text{CDCl}_3$ )  $\delta$  1.08 (t,  $J = 7.0$  Hz, 6,  $\text{CH}_3\text{CH}_2\text{N}$ ), 2.65 (q,  $J = 7.0$  Hz, 4,  $\text{CH}_3\text{CH}_2\text{N}$ ), 2.90 (t,  $J = 6.0$  Hz, 2,  $\text{OCH}_2\text{CH}_2\text{N}$ ), 4.08 (t,  $J = 6.0$  Hz, 2,  $\text{OCH}_2\text{CH}_2\text{N}$ ), 4.94 (d,  $J = 17.2$  Hz, 1m  $\text{CH}=\text{CH}_2$ ), 5.17 (d,  $J = 10.9$  Hz, 1,  $\text{CH}=\text{CH}_2$ ), 6.78-7.26 (m, 9, ArH and  $\text{CH}=\text{CH}_2$ ).  $m/z$  397 (60,  $\text{M}^+$ ). Anal. ( $\text{C}_{28}\text{H}_{31}\text{NO} \cdot 1.5 \text{H}_2\text{O}$ ) C,H,N. Calc., C:79.21, H: 8.06; N:3.30; Found, C:79.76, H:7.56, N:3.09.

1,5 $\text{H}_2\text{O}$  indicates that the sample is either not dry  
25 enough or hygroscopic.

## EXAMPLE 5 - SYNTHESIS OF N,N-DIETHYLHYDROXYMETHYL TAMOXIFEN (COMPOUND III)

30 Clomiphene (3.8 g, 9.3 mmol) was dissolved in tetrahydrofuran (50 ml), cooled to -40°C and then treated with t-butyl lithium (1 M in pentane, 20 mmol). After 10 minutes, trimethylene oxide (6 ml, 93 mmol) was added, the mixture stirred for 16 hours at room temperature, and  
35 then poured into water. The product was extracted with ether and chromatographed on a silica gel column using

1:1:0.1 ether/petroleum ether/ triethylamine as eluant to yield purified *trans*-product (1 g, 25%), m.p. 93-95°C and *cis* product (N,N-diethylhydroxymethyl tamoxifen) (1.0 g, 25%), m.p. 85-87°C. Anal. (C<sub>29</sub>H<sub>35</sub> NO<sub>2</sub>) C,H,N: Calc., C:81.08, H:8.21, N:3.26; Found, C:80.56, H:7.94, N:3.32. Values for aliphatic protons are presented in Table 1.

**EXAMPLE 6 - SYNTHESIS OF CIS-N,N-DIETHYL-O-TOSYLMETHYLTAMOXIFEN (COMPOUND IX)**

10 *Cis*-N,N-diethylhydroxymethyltamoxifen (500 mg, 1.17 mmol) (III) was dissolved in methylene chloride (20 ml), and the solution cooled to 0°C. Pyridine (0.66 ml) and tosyl chloride (266 mg, 1.40 mmol) were added. After 4  
15 hours, the reaction mixture was diluted with additional methylene chloride (20 ml) and washed with water, dried over magnesium sulfate, filtered, and evaporated to yield 476 mg. The crude mixture was chromatographed on a <sup>18</sup>C reverse phase column using 85:15:1  
20 acetonitrile/water/triethylamine as eluant to yield the purified *cis* tosyl analogue of IX (200 mg, 29%, oil) R<sub>f</sub> 0.35 (silica gel plates, ether/petroleum ether/triethylamine 1:1:0.1), m/z 583(10, M<sup>+</sup>). Values for aliphatic protons are presented in Table 1.

25

**EXAMPLE 7 - SYNTHESIS OF N,N-DIETHYLFLUOROMETHYLTAMOXIFEN (COMPOUND VI)**

The *cis*- or *trans*-tosyl analogue of IX (117 mg, 0.2  
30 mmol) was dissolved in tetrahydrofuran (400 µl) according to the inventors' reported procedure.<sup>9</sup> Tetrabutylammonium fluoride (485 µl, 1 M in tetrahydrofuran) was added, and the reaction was warmed to 80°C. After 30 minutes, the reaction was completed.  
35 The mixture was then hydrolyzed with 6N HCl 6.2 ml for 10 min. The product was chromatographed on a silica gel column, which was eluted with 1:1:0.1 ether/petroleum

ether/triethylamine to yield 52 mg (60%, oil) of purified *cis* fluoro product (VI) or 40 mg (46% oil) of *trans* product  $R_f$ :0.80 (silica gel plates, ether/petroleum ether/triethylamine 1:1:01),  $m/z$  431(40,  $M^+$ ). Anal.

5 (C<sub>29</sub>H<sub>34</sub>NOF) C,H,N: Calc., C:80.71, H:7.94, N:3.25; Found, C:80.39, H:8.02, N:3.13 (*cis*) or C:79.58, H:8.01, N:3.20; <sup>1</sup>HNMR AND <sup>13</sup>C-NMR data are shown in Table 2.

10 EXAMPLE 8 - PREPARATION OF N,N-DIETHYLEODOMETHYLTAMOXIFEN (COMPOUND X)

Tosyl analog of tamoxifen (117 mg. 0.2 mmol) was dissolved in acetone (15 ml). Sodium iodide (150 mg, 1.0 mmol) was added, and the reaction was refluxed for 6h.

15 The mixture was evaporated to dryness and chromatographed on a silica gel column using ether/petroleum ether/triethylamine (1:1:15%) eluant to yield *cis* 75 mg (70%)  $R_f$  0.50; or *trans* 54 mg (50%),  $R_f$  0.65 (1% triethylamine in ether/petroleum ether; 1:1).  $m/z$  539 ( $M^+$ , 100), 524(20), 312(30), 191(30), 100(60), 86(100). *trans*  $m/z$  539 ( $M^+$ , 100), 524(30), 452(20), 312(20), 191(30), 100(60), 86(100). The <sup>1</sup>HNMR and <sup>13</sup>CNMR assignments are shown in Table 3.

25 The end product N,N-Diethyliodomethyltamoxifen will then be radiolabeled with <sup>131</sup>I, as described in Example 12.

30 EXAMPLE 9--SYNTHESIS OF N,N-DIETHYLBROMOMETHYLTAMOXIFEN (COMPOUND XI)

The present example is provided to demonstrate the most preferred method and best mode for preparing the bromo-tamoxifen analogs of the present invention.

35 Generally, the bromomethyl-tamoxifen analogs were prepared by treatment of hydroxy precursor with CBr<sub>4</sub> in 50% yields. The IC-50 with (μm) per Br was 0.2. The

-33-

bromomethyl-Tx analogs were found to bind to estrogen receptors greater than other halogenated tamoxifens tested with F, Cl, or I.

#### 5    **Synthesis**

1-[4-(2-Diethylaminoethoxy)phenyl]-1,2-diphenyl-5-bromo-1-entene (N,N-Diethylbromomethyltamoxifen)

Triphenylphosphine (105 mg, 0.4 mmol) was added to a stirred solution of hydroxymethyltamoxifen (85 mg, 0.2 mmol) (1) and carbon tetrabromide (100 mg, 0.6 mmol) in THF (10 ml). After 2h, the reaction mixture was filtered and the filtrate was evaporated to dryness. The mixture was reconstituted in chloroform (100  $\mu$ l) and chromatographed on a silica gel column using ether/petroleum ether/triethylamine (1:1:10%) as eluant to yield the *cis* (36 mg, 37%) or *trans* (39 mg, 40%) product. Elemental analysis - (C<sub>29</sub>H<sub>34</sub>NOBr) C,H,N: Calc. 21  
*Trans* - C:70.72, H:6.96, N:2.84; Found *Trans* - C:70.45, H:7.11, N:2.68; Calc. *Cis*(H<sub>2</sub>O) - C:68.29, H:7.11, N:2.99, Found *Cis* - C:68.70, H:7.63, N:2.74. *Trans* - m/z 493 (20m), 491 (20); *Cis* - m/z 493 (20, M+), 491(20), 267 (20), 252 (30), 191 (40), 86 (100).

#### 25    EXAMPLE 10--SYNTHESIS OF N,N-DIETHYLCHLOROMETHYLAMOXIFEN COMPOUND (XII)

The present example is provided to demonstrate the most preferred method and best mode for preparing the chloro-tamoxifen analogs of the present invention. Generally, the chloromethyl analogs were prepared by treatment of hydroxy precursor with SOCl<sub>2</sub> ( 87% yield). The IC-50 ( $\mu$ M) for Cl was 0.4.

35

Synthesis

1[4-(2-Diethylaminoethoxy)phenyl]-1,2-diphenyl-5-chloro-1-pentene (N,N-Diethylchloromethyltamoxifen)

- 5 Thionyl chloride (1 ml) was added to stirred solution of *cis* or *trans* hydroxymethyltamoxifen (110 mg, 0.26 mmol) in benzene (25 ml). The mixtures were refluxed for 1h. Thin-layer chromatography indicated one spot ( $R_f=0.45$ , Et<sub>2</sub>O/petroleum ether/triethylamine; 10 1:1:10%). The reaction mixtures were evaporated and passed through a silica-gel Sep-Pak column eluted with Et<sub>2</sub>O/petroleum ether/triethylamine (1:1:10%). The *cis* isomer obtained was 100 mg (87%); the *trans* isomer was 90 mg (78%). HPLC analysis showed that the retention time 15 for *cis* isomer was 5.17 min and *trans* isomer was 5.34 min at flow rate 2 ml/min, U.V. = 254 nm, on a C-18 column, mobile phase: acetonitrile:water:triethylamine (85:15:1%); U.V. = 254 nm. Elemental analysis - (C<sub>29</sub>H<sub>34</sub>NOCl) C,H,N: Calc. (*cis=trans*) - C:77.74, H:7.65, 20 N:3.12, Found *Cis* - C:77.28, H:7.83, N:3.01; Found *Trans* - C:77.45, H:7.73, N:2.87. *Trans* - m/z 450 (20, M+), 448 (60), 447 (100); *Cis* - m/z 450 (15, M+), 448 (45), 447(50);

Table 1 -- Elemental Analysis

	Bromide				Chloride		
	Calc.		Found		Calc.	Found	
	H <sub>2</sub> O		<i>Cis</i> (H <sub>2</sub> O)	<i>trans</i>		<i>Cis</i>	<i>trans</i>
C	70.72	68.29	68.70	70.45	77.74	77.28	77.45
H	6.96	7.11	7.63	7.11	7.65	7.83	7.73
N	2.84	2.99	2.74	2.68	3.12	3.01	2.87

**EXAMPLE 11 -  $^1\text{H}$ -NMR AND  $^{13}\text{C}$ -NMR ASSIGNMENT  
OF FLUOROTAMOXIFEN DERIVATIVES**

**$^1\text{H}$ NMR Assignment**

- 5       Assignment of  $^1\text{H}$ -NMR for compound VI and X was done by two dimensional NMR which includes COSY, Long Range COSY and HC COSY, Long Range HC COSY (COSY Homonuclear Chemical Shift Correlation). The aromatic portion is subdivided into three isolated spin systems at 200 MHz.
- 10    In the *trans* isomer, two spin systems were readily established for aromatic protons a and b (Shanni, 1985; McCague, 1988). For compound VI, a correlation among the H1 methylene protons (resonates at 2.76 ppm for *cis* and 2.55 ppm for *trans*), the H2 geminal methylene protons
- 15    (resonates at 1.79 ppm for *cis* and 1.80 ppm for *trans*) and H3 protons (resonates at 4.38 ppm for *cis* and 4.42 ppm for *trans*) was observed during the analysis of the COSY Spectrum as shown in Table 4. In addition, the protons at the 4 and 5 - ethylene bridge correlated with
- 20    each other using the COSY spectrum analysis. H-5 resonates down field at 3.99 ppm (*cis*) and 3.91 ppm (*trans*) whereas H-4 resonates at 2.8 ppm (*cis*) and 2.79 ppm (*trans*). H-6 protons of the ethyl group showed a gradruplet (resonates at 2.57 ppm for *cis* and 2.57 ppm
- 25    for *trans*) which directly correlates with H-7 methyl protons at 1.01 ppm (*cis*) and 1.03 ppm (*trans*). The  $^1\text{H}$ NMR data are shown at Table 2.

**TABLE 2 -  $^1\text{H}$  NMR DATA OF TAMOXIFEN DERIVATIVES**  
 (Carbon number shown at Table 5) < \*\*\*\*\*

5		H-1	J <sub>1,2</sub>	J <sub>1,2</sub>	H-2	H-3	J <sub>3,4</sub>	J <sub>3,4</sub>	H-4
	II ( <i>Cis</i> )	2.79	6.3	6.3	3.96	2.70	7.1	7.1	3.49
10	II ( <i>trans</i> )	2.72	6.2	6.3	3.88	2.76	7.1	7.1	3.54
	III ( <i>Cis</i> )	≈2.48	-	6.3	3.99	≈2.64	-	7.3	1.56
	III ( <i>trans</i> )	≈2.45	-	6.4	3.90	2.77	6.4	7.3	1.59
15	VIII ( <i>Cis</i> )	2.91	6.3	7.1	3.94	2.84	7.1	6.3	4.07
	VIII ( <i>trans</i> )	≈2.80	-	-	≈3.89	≈2.76	-	-	≈3.94
20	LX ( <i>Cis</i> )	2.48	6.0	6.3	3.90	2.90	6.0	7.1	1.66

#### $^{13}\text{C}$ -NMR Assignment

25 Proton resonance assignments were unequivocally assigned by COSY spectrum. Protonated carbon resonance was assigned from HC-COSY spectrum. The chemical shift for *cis* and *trans* isomers of compound VI is shown in Table 3 and for compound X is shown in Table 4.

30

TABLE 3 -  $^{13}\text{C}$  (50 MHz) and  $^1\text{H}$  (200 MHz) NMR ASSIGNMENTS FOR  
N,N-DIETHYLFLUOROMETHYLTAMOXIFEN (VI) in  $\text{CDCl}_3$

Atom	$^1\text{H}$ ( $\pm 0.02$ ppm)		No. of pro- tons	$^1\text{H}$ (multiplicity) $J_{\text{HH}}$ (Hz)		No. of car- bons	$^{13}\text{C}$ (ppm) $J_{\text{CH}}$ (Hz)	
	Trans	Cis		Trans	Cis		Trans	Cis
Ar	7.25	7.23	10H	m	m	6C	130-157	130-157
						10C	126-132	126-131
a	6.79	7.10	2H	d(6.8)	m	1C	113.5	114.2
b	6.56	7.00	2H	d(6.8)	m	1C	113.5	114.2
3	4.42	4.38	2H	dt(7.3)	dt(47.3)	1C	85.2	83.5
				(6.1)	(6.10)		(d;165)	(d;165)
5	3.91	3.99	2H	t(6.4)	t(6.37)	1C	66.3	66.6
4	2.79	2.80	2H	t(6.4)	t(6.37)	1C	51.7	51.9
6	2.56	2.57	4H	m	m	2C	47.8	47.9
1	2.55	2.76	2H	m	m		31.6	31.5
							(d;5.5)	(d;5.5)
2	1.8	1.79	2H	m	m	1C	29.8	29.9
							(d;44.3)	(d;19.5)
7	1.03	1.01	6H	t(7.2)	t(7.2)	2C	11.8	11.8



TABLE 4 -  $^{13}\text{C}$  (50 MHz) and  $^1\text{H}$  (200 MHz) NMR ASSIGNMENTS FOR  
N,N-DIETHYLFLUOROMETHYLTAMOXIFEN (I) in  $\text{CDCl}_3$

	$^1\text{H}$ ( $\pm 0.02$ ppm)	No. of pro- tons	$^1\text{H}$ (multiplicity) $J_{\text{HH}}$ (Hz)	No. of car- bons	$^{13}\text{C}$ (ppm) $J_{\text{HH}}$ (Hz)
Atom	Trans	Cis	Trans/ Cis	Trans	Cis
Ar	7.40	7.20	10H	m	m
				6C	135-157
				10C	126-131
a	6.76	7.10	2H	d(8.8)	m
b	6.54	7.00	2H	d(8.8)	m
5	3.90	4.06	2H	t(6.4)	t(6.4)
4	3.02	3.04	2H	t(7.1)	t(7.0)
3	2.78	2.88	2H	t(6.4)	t(6.4)
6	2.50	2.70	4H	m	m
1	2.50	2.70	2H	m	m
2	1.86	1.86	2H	pent (7.4)	pent (7.4)
7	1.02	1.02	6H	t(7.1)	t(7.1)

## EXAMPLE 12 - RADIOSYNTHESIS OF

20  $[^{18}\text{F}]$  FLUOROMETHYLTAMOXIFEN AND  $[^{131}\text{I}]$  IODOMETHYLTAMOXIFEN  
FROM FLUOROMETHYL TAMOXIFEN AND IODOMETHYL TAMOXIFEN

$[^{18}\text{F}]$ Fluoride was produced at the University of Texas  
Health Science Center, Cyclotron Facility, by proton  
25 irradiation of  $[^{18}\text{O}]$ water (99.4% isotopic enrichment,  
ISOTEC INC., Miamisburg, OH) in a small volume silver  
target. Aliquots containing 50-60 mCi of  $^{18}\text{F}$  were  
combined with kryptofix 222 (26 mg) and potassium  
carbonate (4.6 mg) and dried in a vacutainer tube by  
30 azeotropic distillation with dry acetonitrile. The  
remaining kryptofix/ $[^{18}\text{F}]$ fluoride was resolubilized in  
acetonitrile (3 ml).

[<sup>18</sup>F] FLUOROMETHYLTAMOXIFEN

In a typical procedure, potassium [<sup>18</sup>F]fluoride (from azotropic evaporation of <sup>18</sup>F (H<sub>2</sub><sup>18</sup>O) in acetonitril in the presence of K<sub>2</sub> (03 and Kryptofix 2,2,2) (3 mCi, 200 μl) was transferred to a reaction vessel with the tosylmethyl analog of tamoxifen (compound IX N,N-dimethyl-O-tosylmethyltamoxifen) (1 mg). Tosylmethyl analog was prepared essentially as described in Example 6. The vessel was sealed and warmed at 100°C for 20 minutes, treated with 6 N HCl (200 μl), heated for an additional 10 min, and then spotted on a silica gel coated TLC plate for separation (ether/petroleum ether/triethylamine; 1/1/10% or chloroform/methanol; 9/1).

Authentic non-labeled fluorotamoxifen was used to confirm the presence of F-18 labeled compound. The TLC plate was cut into 0.5 cm zones for counting the activity. Using a Davidson multichannel analyzer fitted with a well type NaI crystal with appropriate shielding. The radiochemical yield was determined as 60%. The reaction mixture was passed through a silica Sep-Pak eluted with 10% triethylamine in ether/petroleum ether (1/1). The radiochemical purity was examined using HPLC (C-18 Radial-Pak column, 8x100 mm, 1% triethylamine in acetonitrile/water [85/15], flowrate of 1.5 ml/min). The retention time of compound VI (N,N-diethylfluoromethyltamoxifen) was 5.60 min. Radiochemical purity was >99%. A typical batch had a specific activity of approximately 4-6 Ci/μmol.

[<sup>131</sup>I] IODOMETHYLTAMOXIFEN

For a typical <sup>131</sup>I displacement experiment, Na<sup>131</sup>I (1mCi) was added to a vial containing tosylmethyltamoxifen (IX) (2mg) in acetone. The reaction was heated at 100°C for 30 min. and 6 N HCl was added. After 20 minutes, the vial was cooled and the reaction

mixture was chromatographed on a silica-gel Sep-Pak column eluted with 1% triethylamine in ether:petroleum ether (1:1). The purity of the [<sup>131</sup>I] labeled tamoxifen analog was assessed by HPLC and compared to authentic  
5 compound. The HPLC retention time for Compound X was 22 minutes (Acetonitrile:water:triethylamine [85:15:1]).

**EXAMPLE 13 - *IN VITRO* ESTROGEN RECEPTOR BINDING -  
VARIOUS TAMOXIFEN DERIVATIVES**

10

The present example demonstrates the ability of the described fluorotamoxifen and iodotamoxifen derivatives to bind estrogen receptors *in vitro* and to demonstrate the utility of employing these tamoxifen derivatives *in*  
15 *vivo* in various diagnostic and therapeutic applications involving imaging of estrogen receptor-containing tissues.

The relative binding affinity of the tamoxifen derivatives synthesized in Examples 1-8 and of native tamoxifen (Compound I) to estrogen receptor was determined a previously reported procedure was modified by the Inventors and used for this purpose.<sup>10, 11</sup> TEA  
20 buffer was used by the Inventors for tissue preparation.

25

Briefly, uteri (90 gm) were obtained from immature domestic swine (15kg) was homogenized in Tris buffer (10 mM, pH 7.4) (1 uterus/180 ml), which contained EDTA (1.5 mM) and sodium Azide (3 mM). The homogenate was  
30 centrifuged at 100,000 g for 1 hour at 4°C. Uteri cytosol (contains 2% of protein from corresponding uterus tissue) were then pretreated with dextran-coated charcoal as described.<sup>10</sup> Protein concentrations were determined according to the method of Lowry et al.<sup>12</sup>

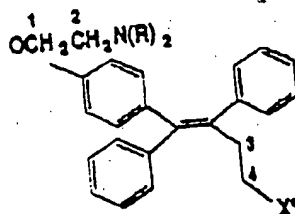
35

To investigate the nature of the interaction of estradiol with the estrogen receptor site, a saturation curve (Figure 2) was obtained for [ $^3\text{H}$ ]estradiol ( $10^{-5}$  M to  $10^{-10}$  M) in the presence or absence of excess estradiol ( $2 \times 10^{-5}$  M). Uteri cytosol (2 mg protein/tube) were incubated at 4°C for 2 h with [ $^3\text{H}$ ]estradiol (5 nM/tube) and competitor [ranging from  $10^{-4}$  M to  $10^{-8}$  M ("specific") or with  $10^{-5}$  M estradiol (non-specific)].

10 A Scatchard analysis indicated a single class of binding sites with a mean  $K_d$  of 5 nM ( $n=9$ ) and a mean  $B_{\text{max}}$  of 376 fmol/mg protein with a Hill coefficient of 0.982 (Figure 3).

15 Various tamoxifen derivatives were then tested for their ability to displace the [ $^3\text{H}$ ]estradiol (5 nM) bound to estrogen receptors in this in vitro pig uterus system. From these experiments, the concentration of test compounds which decreased 50% of specific radioligand binding ( $\text{IC}_{50}$ ) and the inhibition constant ( $K_i$ ) were  
20 determined<sup>9</sup> for various tamoxifen derivatives and the results summarized in Table 4.

Tamoxifen (I) (i.e., the fluorotamoxifen derivative)  
25 binds to the estrogen receptor with high affinity as tamoxifen ( $K_i = 15,000$  nM) (Table I). The affinity of the trans isomer of N,N-diethylfluorotamoxifen (IV) for the estrogen receptor is two and a half times that of tamoxifen. In addition, the trans isomer has a higher  
30 binding affinity than the cis isomer. Increasing the side chain by one carbon resulted in the formation of fluorinated compound VI, which showed a 6-fold (cis) and 30-fold (trans) higher affinity for the estradiol binding site than tamoxifen. The iodinated compound (X) showed  
35 10-15 fold higher estrogen receptor affinity than native tamoxifen.

TABLE 5 - STRUCTURES AND RELATIVE BINDING  
AFFINITIES OF TAMOXIFEN DERIVATIVES

Compound	R	X	RBA*	IC <sub>50</sub> (M)	K <sub>i</sub> (nM)
I (Tamoxifen)	CH <sub>3</sub>	H	100	3x10 <sup>-5</sup>	15,000
II	C <sub>2</sub> H <sub>5</sub>	OH			
III (Cis)	C <sub>2</sub> H <sub>5</sub>	CH <sub>2</sub> OH	300	1x10 <sup>-5</sup>	5,000
(trans)			400	7x10 <sup>-6</sup>	3,500
IV (Cis)	C <sub>2</sub> H <sub>5</sub>	F	100	3x10 <sup>-5</sup>	15,000
(trans)			250	1.2x10 <sup>-5</sup>	6,000
V	CH <sub>3</sub>	OH			
VI (Cis)	C <sub>2</sub> H <sub>5</sub>	CH <sub>2</sub> F	600	5x10 <sup>-6</sup>	2,500
(trans)	C <sub>2</sub> H <sub>5</sub>	CH <sub>2</sub> F	3,000	1x10 <sup>-6</sup>	500
VII (trans)	CH <sub>3</sub>	F	100	3x10 <sup>-5</sup>	15,000
VIII	C <sub>2</sub> H <sub>5</sub>	O- tosyl	-	-	-
IX	C <sub>2</sub> H <sub>5</sub>	CH <sub>2</sub> O- tosyl			
X (cis)	C <sub>2</sub> H <sub>5</sub>	CH <sub>2</sub> I	1,000	3x10 <sup>-6</sup>	1,500
(trans)			1,500	2x10 <sup>-6</sup>	1,000
Estradiol			15,000	2x10 <sup>-7</sup>	100

\* The relative binding affinity (RBA) for the pig uteri estrogen receptor is the ratio between the concentration of unlabeled tamoxifen and the competitor (x 100) (i.e., tamoxifen is 100 as the standard) required to decrease the amount of bound [<sup>3</sup>H]estradiol by 50%. Incubation was done at 4°C. The data was reproduced in triplicate. The protein concentration was determined to be 1 mg per tube.

## EXAMPLE 14

IN VITRO ESTROGEN RECEPTOR BINDING -  
COMPARISON OF HALOGENATED TAMOXIFEN DERIVATIVES

5       The present example is presented to demonstrate the estrogen binding activity of various halogenated tamoxifen analogs. The particular halogenated tamoxifen analogs employed in the present study include:

10                   chloromethyltamoxifen (CMTX);  
                    bromomethyltamoxifen (BrMTX);  
                    fluoromethyltamoxifen (FMTX);  
                    iodomethyltamoxifen (IMTX)

15       The estrogen receptor binding assay used in the present example was essentially the same as described in Example 13.

20       Non-radiochemical forms of the fluoromethyltamoxifen and the iodomethyltamoxifen were prepared by reacting tosylmethyltamoxifen with KF/kryptofix or NaI resulting in 65% and 47% yields, respectively. The radiochemical yields for [<sup>18</sup>F]FMTX and [<sup>131</sup>I]IMTX were 48% and 40%.

25       The chloromethyltamoxifen and bromomethyltamoxifen analogs were prepared by treatment of hydroxytamoxifen precursor with SOCl<sub>2</sub> or CBr<sub>4</sub> resulting in 87% and 50% yields, respectively.

30       The IC<sub>50</sub>'s for fluormethyl, chloromethyl, bromomethyl and iodiomethyl (F, Cl, Br, I and TX) were 1, 0.4, 0.2, 2 and 30 μM, respectively. These data demonstrate that halogenated tamoxifen analogs, as described herein,  
35       compete with [<sup>3</sup>H]estradiol (5 nM) in binding estrogen receptors.

Bromomethyl tamoxifen, as demonstrated in Table 6, binds to estrogen receptors with greater affinity than the other halogenated tamoxifen analogs tested. These alkyl halogenated tamoxifen analogs, particularly the bromo analogs, are thus expected to be particularly efficacious in the mapping estrogen receptors.

TABLE 6  
EFFECT OF HALO ALKYL (METHYLATED) TAMOXIFEN ANALOGS ON  
ESTROGEN RECEPTOR BINDING<sup>1</sup>

Compound	IC <sub>50</sub> (uM) <sup>2</sup>	RBA <sup>3</sup>
F trans	1	30
Cis	5	6
Cl trans	0.4	75
Cis	4	7.5
Br trans	0.2	150
Cis	0.8	37.5
I trans	2	15
Cis	3	10
Tamoxifen trans	30	1
OH trans	7	4
Cis	10	3

- Each value shown for IC<sub>50</sub> and RBA represents the average of three experiments. In each experiment, triplicate samples were tested.
- IC<sub>50</sub>: Concentration required to decrease the amount of bound [<sup>3</sup>H]estradiol by 50%.
- RBA: Relative binding affinity is the IC<sub>50</sub> ratio between tamoxifen and competitor (x100).

**EXAMPLE 15 - INHIBITION OF BREAST TUMOR CELL GROWTH  
IN VITRO BY HALOGENATED TAMOXIFEN ANALOGS**

The present example demonstrates the *in vitro* effect  
5 of fluoro, cloro, bromo and iodo-alkyl halogenated  
tamoxifen analogs on human breast tumor cell growth.  
This *in vitro* test demonstrates also the utility of these  
halogenated tamoxifen analogs for the *in vivo* treatment  
of estrogen-dependent cancers, such as human breast and  
10 uterine cancers. An additional object of this example  
was to establish the utility of using the described  
radiolabeled, alkyl halogenated tamoxifen derivatives as  
imaging agents for imaging estrogen receptor positive  
tumors *in vivo* and to demonstrate the applicability of  
15 using the described alkyl halogenated tamoxifen analogs  
as anti-cancer agents *in vivo*. It is anticipated that  
the presently described halogenated tamoxifen analogs  
will be useful in the treatment of estrogen-dependent  
breast and uterine cancers, as well as other estrogen-  
20 dependent cancer cell growths.

The aliphatically halogenated tamoxifen derivatives  
described herein (Figure 1 and Examples 1-12) were used  
together with an *in vitro* breast tumor cell system to  
25 identify which of these agents might offer advantages  
over other agents currently in use for the treatment and  
diagnosis of estrogen receptive tumors.

The MCF7 cell line is a human tumor cell line. This  
30 cell line was cultured in MEM (Eagles) media in a 5% CO<sub>2</sub>  
atmosphere with 10% fetal calf serum that had been washed  
twice with dextran coated charcoal to reduce endogenous  
estrogen levels. The media was supplemented with 1 mM  
sodium pyruvate and 100  $\mu$ M non-essential amino acids.  
35 The cell line was screened routinely for myoplasma  
contamination using the GenProbe kit (Fisher). Cells  
were trypsinized and plated at a density of 5,000



cells/well in 96 well microtiter plates and allowed to attach and recover for 24 hours.

The media was removed by aspiration and replaced  
5 with filter sterilized drug (concentration from  $10^{-4}$ M to  $10^{-5}$ M) in media. The cells were incubated for 72 hours and then stained using the MTT tetrazolium dye assay of Mosmann<sup>36</sup> except that after the media was removed, the blue formazan product was solubilized in 50  $\mu$ l/well DMSO.  
10 Plates were shaken for 1 minute and read on a Dynatech MR600 microplate reader within an hour at a transmission wavelength of 570 nm and reference wavelength of 630 nm.

Compound III (N,N-diethylhydroxymethyltamoxifen), IV  
15 (N,N-diethylfluorotamoxifen), VI (N,N-diethylfluoromethyltamoxifen), VII (fluorotamoxifen), X (N,N-diethyliodomethyltamoxifen), XI (N,N-diethylbromomethyltamoxifen), and XII (N,N-diethylchloromethyltamoxifen) were prepared substantially as  
20 described in Examples 1-10.

The results of the 72 hour exposure of MCF7 tumor cell line to tamoxifen or analogs are summarized in Table 6. *cis* N,N-diethylfluoromethyltamoxifen was 3-fold more  
25 potent than tamoxifen control against this tumor cell line. In addition, both *cis* N,N-diethyl-fluoro, fluoromethyl- and iodomethyl isomers appear to be more potent than the *trans* isomers.

30 These results demonstrate that the described fluorotamoxifen derivatives, particularly compounds IV (*cis*), VI (*cis* and *trans*) and X (*cis* and *trans*) are effective as inhibiting a breast tumor cell line, and further support the reasonable expectation that these  
35 highly specific derivatives would be effective as an anti-cancer agent in treating human breast cancer.

In summary, this study demonstrates that halogenated tamoxifens with the halogen atom placed on the aliphatic chain bind to estrogen receptors *in vitro* and can be labeled with  $^{18}\text{F}$  and  $^{131}\text{I}$ , thus reflecting a utility for imaging estrogen receptors by PET and SPECT. Also, the data obtained from *in vitro* receptor assays suggested that the disclosed tamoxifen derivatives, particularly N,N-diethylfluoromethyltamoxifen and N,N-diethyliodomethyltamoxifen, may be potential ligands for mapping the estrogen receptor by PET and SPECT.

TABLE 7  
EFFECT OF HALOGENATED TAMOXIFEN ANALOGS ON  
HUMAN BREAST TUMOR CELL GROWTH *IN VITRO*<sup>1</sup>

Compound	IC <sub>50</sub> Dose ( $\mu\text{M}$ ) <sup>2</sup>	RP <sup>3</sup>
trans-tamoxifen (control)	1.0 (14.6)	100
(III) OH (Cis)	16.7	66
(trans)	22.0	50
(IV) F (Cis)	4.1	268
(trans)	13.4	82
(VI) FM (Cis)	4.5	244
(trans)	11.8	93
(VII) FTX (Cis)	4.5	224
(trans)	11.8	93
(X) IM (Cis)	2.36	466
(trans)	6.3	175
(XI) BrM (Cis)	0.62	2355
(trans)	4.9	298
(XII) ClM (Cis)	4.36	335
(trans)	10.0	146

1. Cell line used was MCF7. Data represents average of three experiments.

2. IC<sub>50</sub> indicates the concentrations required to inhibit 50% of MCF<sub>7</sub> cells growth.

3. Relative potency (RP) indicates the IC<sub>50</sub> ratio between tamoxifen and competitor.

## EXAMPLE 16

IN VIVO BIODISTRIBUTION IN RATS OF ADMINISTERED  
N,N-DIETHYL- $^{18}\text{F}$ FLUOROMETHYLTAMOXIFEN (VI)

5

The present example is presented to demonstrate the particular biodistribution characteristics of an alkyl halogenated tamoxifen derivative administered in an *in vivo* system.

10

Four groups of rats (150-200 gm, N = 4/group) were anesthetized with ketamine (10-15 mg/rat). Pure N,N-diethyl- $^{18}\text{F}$ fluoromethyltamoxifen (specific activity > 6 Ci/ $\mu\text{mol}$ ) was reconstructed in 5% ethanol-saline solution, and 10  $\mu\text{Ci}$  of this tracer was given (i.v., tail-vein) into estrogen-primed female Sprague-Dawley rats ("primed" = 60  $\mu\text{g}$  estradiol, s.c., 3 days). Tissue uptake of  $^{18}\text{F}$ -tracer was determined at 2 and 4 hours (h). To ascertain whether the  $^{18}\text{F}$ -tracer uptake was mediated by a receptor-process, one group of rats was given  $^{18}\text{F}$ -tracer without priming with estradiol; and another group of rats was given unlabeled estradiol (30  $\mu\text{g}$ /rat) together with  $^{18}\text{F}$ -tracer. The amount of unlabeled estradiol given to rats should occupy estrogen receptors and chase out the  $^{18}\text{F}$ -tracer's radioactivity from uterus.

15

20

25

TABLE 8  
BIODISTRIBUTION OF N,N-DIETHYL- $^{18}\text{F}$ FLUOROMETHYLTAMOXIFEN

5     % OF INJECTED DOSE/GRAM OF TISSUE WEIGHT OF RAT (N=4)  
      (PRIME WITH 60  $\mu\text{g}$  OF ESTRADIOL FOR 3 DAYS)

	2h	4h	2h(BLOCK) <sup>1</sup>	2h*
10 BLOOD	0.033 $\pm$ 0.0059	0.045 $\pm$ 0.0003	0.048 $\pm$ 0.0066	0.033 $\pm$ 0.0109
LIVER	4.540 $\pm$ 0.5053	4.205 $\pm$ 0.4397	4.451 $\pm$ 1.1559	3.849 $\pm$ 0.4069
KIDNEY	0.742 $\pm$ 0.0756	0.796 $\pm$ 0.0300	0.742 $\pm$ 0.1451	0.530 $\pm$ 0.0752
UTERUS	0.426 $\pm$ 0.0177	0.400 $\pm$ 0.0312	0.297 $\pm$ 0.0356	0.248 $\pm$ 0.0535
MUSCLE	0.151 $\pm$ 0.0203	0.183 $\pm$ 0.0015	0.145 $\pm$ 0.0446	0.109 $\pm$ 0.0218
BONE	0.653 $\pm$ 0.1348	0.802 $\pm$ 0.0556	0.576 $\pm$ 0.1268	0.644 $\pm$ 0.0656
15 INTES- TINE	0.917 $\pm$ 0.3058	1.101 $\pm$ 0.5986	0.742 $\pm$ 0.458	0.504 $\pm$ 0.1784
UTERUS/ BLOOD	13.5 $\pm$ 2.97	9.1 $\pm$ 1.34	6.3 $\pm$ 1.62	6.6 $\pm$ 0.29
20 UTERUS/ MUSCLE	2.9 $\pm$ 0.43	2.2 $\pm$ 0.16	2.2 $\pm$ 0.62	2.5 $\pm$ 0.37

1 Rats were coinjected with estradiol (30 $\mu\text{g}$ ) and F-18 tracer in the blocked group.

25 \*Without prime with estradiol (control); rats weighted about 175 gm.

30     The uterus to blood ratio at 2 h in rats without  
      priming with estradiol group was 6.6  $\pm$  0.29, which  
      changed to 13.5  $\pm$  2.97 in rats primed with estradiol.  
      This increased uptake was blocked by coinjection of  
      estradiol and  $^{18}\text{F}$ -tracer, where the ratio was 6.3  $\pm$  1.62.  
      The data suggest that the uterus uptake by  $^{18}\text{F}$ -fluoro  
      analogue of tamoxifen is mediated by an estrogen receptor  
35     process.

**PROPHETIC EXAMPLE 17 - PROPOSED HUMAN USE OF  
ALKYL HALOGENATED TAMOXIFEN AND DERIVATIVES AS LIGANDS  
LEGENDS FOR IMAGING ESTROGEN RECEPTOR POSITIVE TUMORS**

5       The present prophetic example is provided to outline  
a procedure for the potential utility of the disclosed  
tamoxifen analogs in imaging estrogen-receptor positive  
tumor cells in humans. More specifically, the present  
prophetic example is aimed at outlining a method by which  
10       the described lower alkyl halo tamoxifen derivatives  
molecules may be used to image estrogen receptor positive  
tumors *in vivo*, most particularly those which typically  
occur in breast tissue and uterine tissue.

15       In a most preferred embodiment of the proposed  
method, the lower alkyl halotamoxifen derivative, *trans*-  
*N,N*-diethylfluoromethyltamoxifen (compound VI), *trans*  
*N,N*-diethylthyl iodomethyltamoxifen (compound X), or  
bromomethyltamoxifen are the radiopharmaceuticals of  
20       choice to be used as the estrogen receptor imaging agent  
in a standard PET (positron emission tomography) and  
SPECT analysis. Of these, bromomethyltamoxifen produced  
the most superior results in animal studies presented by  
the Inventors.

25       The procedure for conducting estrogen receptor  
mapping would be substantially the same as that outlined  
by Minton *et al.*<sup>4</sup> The most significant modification of  
this procedure, among others, is that the estradiol-based  
30       derivatives described by Minton would not be used, and  
instead the aliphatic chain substituted tamoxifen  
derivatives of the claimed invention would be used.

35       Briefly stated, the most preferred method for  
imaging estrogen receptors in breast tumor tissue of a  
patient, wherein a radiolabeled alkyl-halogenated  
tamoxifen derivative (such as *N,N*-

diethyl[<sup>18</sup>F]fluoromethyltamoxifen, N,N-diethyl  
[<sup>131</sup>I]iodomethyltamoxifen, N,N-diethylchloromethyltamoxifen  
or N,N-diethylbromomethyltamoxifen) is employed as the  
imaging agent, comprises the following steps:

- 5 administering to the patient a sufficient amount (about  
10 mCi) of radiolabeled alkyl-halogenated tamoxifen  
derivative to the breast tissue of the patient. The  
patient is then to be placed in a supine position in the  
PET device, at which time an emission scan of the chest  
10 at the level of the breast mass is to be performed. The  
technique for performing an emission scan of the chest is  
well known to those of skill in the art, and the general  
procedure for this technique is described by Mintun et  
al.,<sup>4</sup> which reference is specifically incorporated herein  
15 for this purpose.

Most preferably, the emission consecutive transaxial  
scan is to be performed for a 15 minute duration and most  
preferably about 110 minutes after the injection of the  
20 radiolabeled alkyl halogenated tamoxifen derivative.  
Most preferably, the tumor location is to be confirmed by  
palpation of the tissue after the patient is in the  
described supine position. The  $\mu\text{Ci/ml/pixel}$  of tumor  
uptake will then be determined.

- 25 The PET images obtained are then to be evaluated for  
the presence or absence of focally increased uptake of  
the radiolabeled alkyl halogenated tamoxifen  
fluorotamoxifen ligand in the breasts and in the axillae  
30 as these were included in the field of view of the PET  
scanner. Those sites determined from the PET images to  
have demonstrated potential uptake are to be designated  
as accordingly abnormal foci uptake of the radiolabeled  
alkyl halogenated tamoxifen derivative.

The most preferred radiolabeled alkyl halogenated tamoxifen derivative to be used in the mapping and imaging of estrogen receptors in human tissue is N,N-diethylbromomethyltamoxifen.

5

**PROPHETIC EXAMPLE 18 - PROPOSED USE OF  
ALKYL HALOGENATED TAMOXIFEN AND DERIVATIVES  
IN TREATING CANCER**

10

The present prophetic example is provided to outline a procedure which could be employed for the potential utility of the described alkyl-halogenated tamoxifen derivatives in a treatment regimen for cancer in an animal.

15

While all of the aliphatic chain substituted tamoxifen derivatives described herein are expected to be useful in an animal treatment regimen, the lower alkyl halotamoxifen derivatives are most preferred. Among the lower alky halogen tamoxifen derivatives described herein, N,N-diethylfluoromethyltamoxifen is most particularly preferred.

20

The methods are postulated to be effective in the treatment of cancers which are estrogen-receptor positive, such as estrogen receptor positive breast cancers. The frequency and dosage amount of the disclosed tamoxifen derivatives would be optimized according to standard techniques, which are well known to those skilled in the art.

25

30

The following references are specifically incorporated herein by reference in pertinent part for the reasons indicated herein.

5

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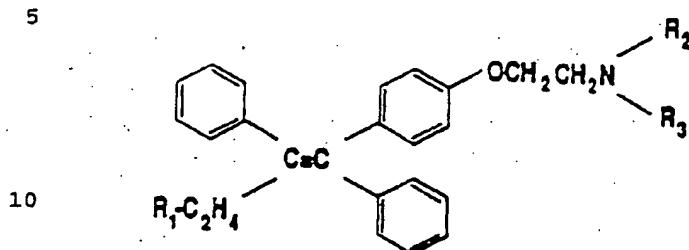


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CLAIMS:

1. A tamoxifen derivative which is a compound of formula (1):



wherein  $R_1$  is a halide lower halo-alkyl or a lower hydroxy alkyl;  $R_2$  is a lower alkyl and  $R_3$  is a lower alkyl.

2. The tamoxifen derivative of claim 1 wherein  $R_1$  is halide defined as fluorine, iodine, bromine or chloride.

3. The tamoxifen derivative of claim 1 wherein  $R_1$  is a lower halo-alkyl defined as fluoromethyl, iodomethyl, chloromethyl, or bromomethyl.

4. The tamoxifen derivative of claim 1 wherein  $R_1$  is a lower hydroxy alkyl defined as hydroxymethyl.

5. The tamoxifen derivative of claim 1 wherein  $R_1$  is fluoromethyl.

6. The tamoxifen derivative of claim 1 wherein  $R_1$  is iodomethyl.

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7. The tamoxifen derivative of claim 1 wherein  $R_1$  is bromomethyl.

5 8. The tamoxifen derivative of claim 1 wherein  $R_1$  is chloromethyl.

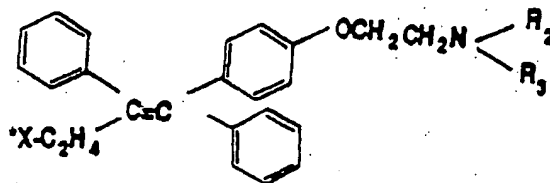
9. The tamoxifen derivative of claim 1 wherein  $R_2$  and  $R_3$   
10 are methyl or ethyl and wherein  $R_2$  is not methyl when  $R_3$  is methyl.

10. The tamoxifen derivative of claim 1, 2, 3, 4 or 5  
15 wherein  $R_2$  and  $R_3$  are ethyl.

11. The tamoxifen derivative of claim 5 or 6 having a  
20 binding affinity for estrogen receptors of at least thirty times greater than native tamoxifen.

12. A radiolabeled tamoxifen derivative which is a  
compound of formula (2)

25



30

wherein  $*X$  is  $[18-F]$ fluoromethyl, or  $[131-I]$ iodomethyl,  $[I-123]$ iodomethyl,  $[^{75}Br]$ bromomethyl or  $[^{77}Br]$ bromomethyl or  $[Cl]$ chloromethyl;  $R_2$  is methyl or ethyl; wherein  $R_3$  is methyl or ethyl.

35

13. The radiolabeled tamoxifen derivative of claim 12 wherein  $R_2$  is not methyl when  $R_3$  is methyl.

14. The radiolabeled tamoxifen derivatives of claim 9 wherein  $R_2$  is ethyl and  $R_3$  is ethyl.

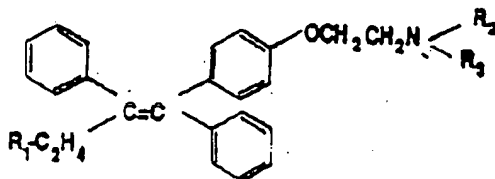
15. The radiolabeled tamoxifen derivative of claim 9 wherein X is [18-F]fluoromethyl or [131-I]iodomethyl.

16. The radiolabeled tamoxifen derivative of claim 9 wherein X is [18-F]fluoromethyl and  $R_2$  and  $R_3$  are ethyl.

17. The radiolabeled tamoxifen derivative of claim 9 wherein X is [ $^{75}\text{Br}$ ]bromomethyl or [ $^{77}\text{Br}$ ]bromomethyl.

18. The radiolabeled tamoxifen derivative of claim 9 wherein X is [ $^{75}\text{Br}$ ]bromomethyl or [ $^{77}\text{Br}$ ]bromomethyl and  $R_2$  and  $R_3$  are ethyl.

19. A method for inhibiting an estrogen-receptor positive tumor in a patient comprising administering to the patient a tumor-inhibiting tamoxifen derivative which is a compound of formula 1



wherein  $R_1$  is a halide, a lower halo-alkyl or a lower hydroxy alkyl;  $R_2$  is a lower alkyl; and  $R_3$  is a lower alkyl.

5

20. The method of claim 19 wherein the tamoxifen derivative is further defined wherein  $R_1$  is a halogen;  $R_2$  is methyl or ethyl;  $R_3$  is methyl or ethyl and wherein  $R_2$  is not methyl when  $R_3$  is methyl.

10

21. The method of claim 19 wherein the tamoxifen derivative is further defined wherein  $R_1$  is the halogen bromine, chlorine, fluorine or iodine.

15

22. The method of claim 19 wherein the tamoxifen derivative is further defined wherein  $R_1$  is the halogen fluorine,  $R_2$  is the lower alkyl ethyl, and  $R_3$  is the lower alkyl ethyl.

20

23. A radiopharmaceutical having binding affinity for estrogen receptors comprising a radiolabeled tamoxifen derivative, wherein the radiolabel comprises  $^{18}\text{F}$ ,  $^{131}\text{I}$ , or  $^{77}\text{Br}$  and wherein the tamoxifen derivative is substituted at an alkyl side chain of the tamoxifen molecule.

25

30 24. The radiopharmaceutical of claim 23, wherein the alkyl side chain comprises a chain of at least two carbons.

25. The radiopharmaceutical of claim 23, defined as comprising an  $^{18}\text{F}$  radiolabel and as comprising  $^{18}\text{F}$ -N,N-diethylfluoromethyltamoxifen or  $^{18}\text{F}$ -fluoromethyltamoxifen.
- 5
26. The radiopharmaceutical of claim 23, which is iodomethyltamoxifen comprising an  $^{131}\text{I}$  radiolabel.
- 10
27. The estrogen receptor radiopharmaceutical agent of claim 23, which is bromomethyl tamoxifen comprising a  $^{77}\text{Br}$  radiolabel.
- 15
28. The estrogen receptor radiopharmaceutical agent of claim 22 defined as N,N-dimethylchloromethyltamoxifen.
- 20
29. A method for preparing a radiolabeled lower halo-alkyl tamoxifen derivative comprising the steps of:
- dissolving a quantity of clomiphene in a sufficient volume of tetrahydrofuran to form a reaction mixture;
- 25
- adding t-butyl lithium and trimethyl oxide to the reaction mixture to form a second reaction mixture;
- 30
- extracting the second reaction mixture with ether and collecting an ether layer containing N,N-diethyl hydroxymethyltamoxifen;
- 35
- isolating the N,N-diethyl hydroxymethyltamoxifen from the ether layer;

dissolving the N,N-diethyl hydroxymethyltamoxifen in methylene chloride and adding thereto pyridine and tosyl chloride to form a third reaction mixture;

5

diluting the third reaction mixture with methylene chloride and isolating a methylene chloride layer containing a tosyl analog of tamoxifen;

10

isolating the tosyl analog of tamoxifen from the methylene chloride layer;

displacing the tosyl with Na<sup>18</sup>F or Na<sup>131</sup>I to produce a radiolabeled alkyl halogenated tamoxifen derivative.

15

30. The alkyl method of claim 29 wherein the radiolabeled lower halo-alkyl tamoxifen derivative is <sup>18</sup>F-fluoromethyltamoxifen.

20

31. The method of claim 29 wherein the tosyl group is displaced with Na<sup>131</sup>I and the radiolabeled lower halo-alkyl tamoxifen derivative is <sup>131</sup>I-iodomethyltamoxifen.

25

32. The method of claim 29 wherein the radiolabeled lower-alkyl tamoxifen derivative is <sup>18</sup>F-N,N-diethylfluorotamoxifen, <sup>18</sup>F-N,N-diethylfluoromethyltamoxifen, or <sup>131</sup>I-N,N-diethyliodomethyltamoxifen.

30

33. The method of claim 29 wherein the radiolabeled tamoxifen derivative is [18-F]N,N-diethylfluoromethyltamoxifen.

35



34. The method of claim 29 wherein the tosyl analog of tamoxifen is N,N-diethyl-O-tosyltamoxifen or N,N-dimethyl-O-tosyltamoxifen.

5

35. The method of claim 29 wherein the radiolabeled alkyl halogenated tamoxifen derivative is N,N-diethyltamoxifen.

10

36. The method of claim 29, wherein the lower halo-alkyl tamoxifen derivative is a *cis* isomer of a methyl halotamoxifen derivative.

15

37. A method for preparing an alkyl halogenated methyl tamoxifen derivative comprising the steps of:

20 dissolving a quantity of clomiphene in a volume of t-butyl;

forming a mixture containing N,N-dimethylhydroxymethyl tamoxifen;

25

isolating the N,N-dimethylhydroxymethyltamoxifen in methylene chloride and adding thereto pyridine and tosyl chloride;

30 diluting the mixture with methylene chloride and isolating a methylene chloride layer containing a tosyl analog of tamoxifen;

isolating the tosyl analog of tamoxifen;

35

adding tetrabutylammonium fluoride or sodium iodide to form a mixture comprising a fluoride or iodide labeled N,N-diethylhydroxymethyl-tamoxifen; and

5

isolating the alkyl halogenated methyl tamoxifen derivative.

10 38. A method for imaging estrogen receptors in an estrogen receptor-rich tissue of a patient comprising labeling the estrogen receptor with a radiolabeled halo tamoxifen derivative comprising the steps of:

15 administering a sufficient quantity of the radiolabeled lower alkyl-halo tamoxifen derivative to an estrogen receptor rich tissue of the patient;

20 positioning the patient spine in a PET device;

performing an emission scan of the estrogen-receptor rich tissue, and obtaining a PET image of the tissue; and

25

evaluating the PET image for the presence or absence of focally increased uptake of the radiolabel in the tissue.

30

39. The method of claim 41 wherein the radiolabeled alkyl halogenated tamoxifen derivative is trans-[18-F]fluoromethyl-diethyltamoxifen.

35

40. The method of claim 38 wherein the radiolabeled halotamoxifen derivative is [<sup>131</sup>I]iodomethyl N,N-diethyltamoxifen.
- 5 41. The method of claim 38 wherein the radiolabeled halotamoxifen derivative is [<sup>77</sup>Br]bromomethyl N,N-diethyltamoxifen.
- 10 42. The method of claim 38 wherein the alkyl halotamoxifen derivative is [<sup>131</sup>I]iodomethyltamoxifen.
- 15 43. The method of claim 38 wherein the alkyl halotamoxifen derivative is chloromethyltamoxifen.
- 20 44. The method of claim 38 wherein the radiolabeled alkyl halogenated tamoxifen derivative is [<sup>77</sup>Br]bromomethyltamoxifen.
- 25 45. The method of claim 38 wherein the estrogen receptor-rich tissue is breast tissue.
- 30 46. The method of claim 38 wherein the emission scan is performed for between about 15 minutes following administration of the alkyl-halogenated tamoxifen derivative.
- 35 47. The method of claim 38 wherein the emission scan is performed about 110 minutes after the administration of the alkyl-halogenated tamoxifen derivative.

48. A pharmaceutical agent for the radiotherapy of a  
estrogen hormone dependent tumor comprising a  
radiolabeled alkyl halotamoxifen derivative, wherein said  
radiolabeled alkyl halotamoxifen derivative is:  
5     $[^{18}\text{F}]$ fluoromethyl N,N-diethyl-tamoxifen,  $[^{131}\text{I}]$ iodomethyl  
or  $[^{77}\text{Br}]$ bromomethyl N,N-diethyl tamoxifen.

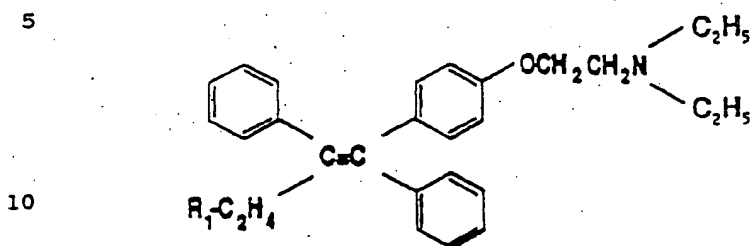
49. The pharmaceutical agent of claim 48 wherein the  
10   radiolabeled alkyl halotamoxifen derivative is  
      $[^{77}\text{Br}]$ bromoethyl N,N-diethyltamoxifen.

50. The pharmaceutical agent of claim 48 wherein the  
15   radiolabeled alkyl halotamoxifen derivative is  
      $[^{18}\text{F}]$ fluoromethyl-N,N-diethyltamoxifen.

## AMENDED CLAIMS

[received by the International Bureau  
on 24 March 1992 (24.03.92);  
original claims 1-50 replaced by amended  
claims 1-47 (9 pages)]

1. A tamoxifen derivative which is a compound of  
formula (1):



wherein  $R_1$  is a halide lower halo-alkyl or a lower hydroxy  
alkyl.

15

2. The tamoxifen derivative of claim 1 wherein  $R_1$  is  
halide defined as fluorine, iodine, bromine or chloride.

20

3. The tamoxifen derivative of claim 1 wherein  $R_1$  is a  
lower halo-alkyl defined as fluoromethyl, iodomethyl,  
chloromethyl, or bromomethyl.

25

4. The tamoxifen derivative of claim 1 wherein  $R_1$  is a  
lower hydroxy alkyl defined as hydroxymethyl.

30

5. The tamoxifen derivative of claim 1 wherein  $R_1$  is  
fluoromethyl.

6. The tamoxifen derivative of claim 1 wherein  $R_1$  is iodomethyl.

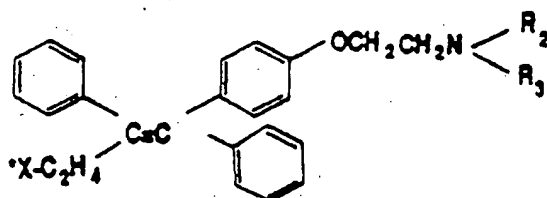
5 7. The tamoxifen derivative of claim 1 wherein  $R_1$  is bromomethyl.

8. The tamoxifen derivative of claim 1 wherein  $R_1$  is  
10 chloromethyl.

9. The tamoxifen derivative of claim 5 or 6 having a  
binding affinity for estrogen receptors of at least  
15 thirty times greater than native tamoxifen.

10. A radiolabeled tamoxifen derivative which is a  
compound of formula (2)

20



25

wherein 'X' is [18-F]fluoromethyl, or [131-I]iodomethyl,  
[I-123]iodomethyl, [<sup>75</sup>Br]bromomethyl or [<sup>77</sup>Br]bromomethyl  
or [Cl]chloromethyl;  $R_2$  is methyl or ethyl; wherein  $R_3$   
is methyl or ethyl.

30

11. The radiolabeled tamoxifen derivative of claim 10  
wherein  $R_2$  is not methyl when  $R_3$  is methyl.

35

12. The radiolabeled tamoxifen derivative of claim 10

wherein X is [18-F]fluoromethyl or [131-I]iodomethyl.

13. The radiolabeled tamoxifen derivative of claim 10  
5 wherein X is [18-F]fluoromethyl.

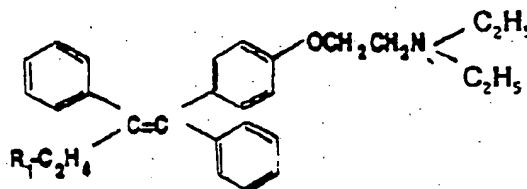
14. The radiolabeled tamoxifen derivative of claim 10  
10 wherein X is [<sup>75</sup>Br]bromomethyl or [<sup>77</sup>Br]bromomethyl.

15. The radiolabeled tamoxifen derivative of claim 10  
wherein X is [<sup>75</sup>Br]bromomethyl or [<sup>77</sup>Br]bromomethyl.

15

16. A method for inhibiting an estrogen-receptor  
positive tumor in a patient comprising administering to  
the patient a tumor-inhibiting tamoxifen derivative which  
is a compound of formula 1

20



25

wherein  $R_1$  is a halide, a halogen, a lower halo-alkyl or a  
lower hydroxy alkyl.

30

17. The method of claim 16 wherein the tamoxifen  
derivative is further defined wherein  $R_1$  is a halogen.

35

18. The method of claim 16 wherein the tamoxifen  
derivative is further defined wherein  $R_1$  is the halogen

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bromine, chlorine, fluorine or iodine.

19. The method of claim 16 wherein the tamoxifen  
5 derivative is further defined wherein R<sub>1</sub> is the halogen  
fluorine.

20. A radiopharmaceutical having binding affinity for  
10 estrogen receptors comprising a radiolabeled tamoxifen  
derivative, wherein the radiolabel comprises <sup>18</sup>F, <sup>131</sup>I, or  
<sup>77</sup>Br and wherein the tamoxifen derivative is substituted  
at an alkyl side chain of the tamoxifen molecule.

15 21. The radiopharmaceutical of claim 20, wherein the  
alkyl side chain comprises a chain of at least two  
carbons.

20 22. The radiopharmaceutical of claim 20, defined as  
comprising an <sup>18</sup>F radiolabel and as comprising <sup>18</sup>F-N,N-  
diethylfluoromethyltamoxifen or <sup>18</sup>F-fluoromethyltamoxifen.

25 23. The radiopharmaceutical of claim 20, which is  
iodomethyltamoxifen comprising an <sup>131</sup>I radiolabel.

30 24. The estrogen receptor radiopharmaceutical agent of  
claim 20, which is bromomethyl tamoxifen comprising a <sup>77</sup>Br  
radiolabel.

35 25. The estrogen receptor radiopharmaceutical agent of  
claim 20 defined as N,N-dimethylchloromethyltamoxifen.



26. A method for preparing a radiolabeled lower halo-alkyl tamoxifen derivative comprising the steps of:

- 5       dissolving a quantity of clomiphene in a sufficient volume of tetrahydrofuran to form a reaction mixture;
- adding t-butyl lithium and trimethyl oxide to the
- 10       reaction mixture to form a second reaction mixture;
- extracting the second reaction mixture with ether and collecting an ether layer containing N,N-
- 15       diethyl hydroxymethyltamoxifen;
- isolating the N,N-diethyl hydroxymethyltamoxifen from the ether layer;
- 20       dissolving the N,N-diethyl hydroxymethyltamoxifen in methylene chloride and adding thereto pyridine and tosyl chloride to form a third reaction mixture;
- 25       diluting the third reaction mixture with methylene chloride and isolating a methylene chloride layer containing a tosyl analog of tamoxifen;
- isolating the tosyl analog of tamoxifen from the
- 30       methylene chloride layer;
- displacing the tosyl with  $\text{Na}^{18}\text{F}$  or  $\text{Na}^{131}\text{I}$  to produce a radiolabeled alkyl halogenated tamoxifen derivative.

35

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27. The alkyl method of claim 26 wherein the radiolabeled lower halo-alkyl tamoxifen derivative is  $^{18}\text{F}$ -fluoromethyltamoxifen.

5

28. The method of claim 26 wherein the tosyl group is displaced with  $\text{Na}^{131}\text{I}$  and the radiolabeled lower halo-alkyl tamoxifen derivative is  $^{131}\text{I}$ -iodomethyltamoxifen.

10

29. The method of claim 26 wherein the radiolabeled lower-alkyl tamoxifen derivative is  $^{18}\text{F}$ -N,N-diethylfluorotamoxifen,  $^{18}\text{F}$ -N,N-diethylfluoromethyltamoxifen, or  $^{131}\text{I}$ -N,N-diethyliodomethyltamoxifen.

15

30. The method of claim 26 wherein the radiolabeled tamoxifen derivative is  $^{18}\text{F}$ -N,N-diethylfluoromethyltamoxifen.

20

31. The method of claim 26 wherein the tosyl analog of tamoxifen is N,N-diethyl-O-tosyltamoxifen or N,N-dimethyl-O-tosyltamoxifen.

25

32. The method of claim 26 wherein the radiolabeled alkyl halogenated tamoxifen derivative is N,N-diethyltamoxifen.

30

33. The method of claim 26, wherein the lower halo-alkyl tamoxifen derivative is a cis isomer of a methyl halotamoxifen derivative.

35

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34. A method for preparing an alkyl halogenated methyl tamoxifen derivative comprising the steps of:

- 5           dissolving a quantity of clomiphene in a volume of  
            t-butyl;
- forming a mixture containing N,N-  
            dimethylhydroxymethyl tamoxifen;
- 10          isolating the N,N-dimethylhydroxymethyltamoxifen in  
            methylene chloride and adding thereto pyridine  
            and tosyl chloride;
- diluting the mixture with methylene chloride and  
15          isolating a methylene chloride layer containing  
            a tosyl analog of tamoxifen;
- isolating the tosyl analog of tamoxifen;
- 20          adding tetrabutylammonium fluoride or sodium iodide  
            to form a mixture comprising a fluoride or  
            iodide labeled N,N-diethylhydroxymethyl-  
            tamoxifen; and
- 25          isolating the alkyl halogenated methyl tamoxifen  
            derivative.

35. A method for imaging estrogen receptors in an  
30   estrogen receptor-rich tissue of a patient comprising  
     labeling the estrogen receptor with a radiolabeled halo  
     tamoxifen derivative comprising the steps of:

- administering a sufficient quantity of the  
35          radiolabeled lower alkyl-halo tamoxifen  
            derivative to an estrogen receptor rich tissue

of the patient;

positioning the patient spine in a PET device;

5 performing an emission scan of the estrogen-receptor  
rich tissue, and obtaining a PET image of the  
tissue; and

10 evaluating the PET image for the presence or absence  
of focally increased uptake of the radiolabel in  
the tissue.

36. The method of claim 35 wherein the radiolabeled  
15 alkyl halogenated tamoxifen derivative is trans-[18-  
F]fluoromethyl-diethyltamoxifen.

37. The method of claim 35 wherein the radiolabeled  
20 halotamoxifen derivative is [131-I]iodomethyl  
N,N-diethyltamoxifen.

38. The method of claim 35 wherein the radiolabeled  
halotamoxifen derivative is [<sup>77</sup>Br]bromomethyl  
25 N,N-diethyltamoxifen.

39. The method of claim 35 wherein the alkyl  
halotamoxifen derivative is [<sup>131</sup>I]iodomethyltamoxifen.  
30

40. The method of claim 35 wherein the alkyl  
halotamoxifen derivative is chloromethyltamoxifen.

35 41. The method of claim 35 wherein the radiolabeled

alkyl halogenated tamoxifen derivative is  
[<sup>77</sup>Br]bromomethyltamoxifen.

5 42. The method of claim 35 wherein the estrogen  
receptor-rich tissue is breast tissue.

43. The method of claim 35 wherein the emission scan is  
10 performed for between about 15 minutes following  
administration of the alkyl-halogenated tamoxifen  
derivative.

15 44. The method of claim 35 wherein the emission scan is  
performed about 110 minutes after the administration of  
the alkyl-halogenated tamoxifen derivative.

20 45. A pharmaceutical agent for the radiotherapy of a  
estrogen hormone dependent tumor comprising a  
radiolabeled alkyl halotamoxifen derivative, wherein said  
radiolabeled alkyl halotamoxifen derivative is:  
[<sup>18</sup>F]fluoromethyl N,N-diethyl-tamoxifen, [<sup>131</sup>I]iodomethyl  
25 or [<sup>77</sup>Br]bromomethyl N,N-diethyl tamoxifen.

46. The pharmaceutical agent of claim 45 wherein the  
radiolabeled alkyl halotamoxifen derivative is  
30 [<sup>77</sup>Br]bromoethyl N,N-diethyltamoxifen.

47. The pharmaceutical agent of claim 45 wherein the  
radiolabeled alkyl halotamoxifen derivative is  
35 [<sup>18</sup>]fluoromethyl-N,N-diethyltamoxifen.

## STATEMENT UNDER ARTICLE 19.

Claim 1 has been amended to define a chemical structure which includes an N,N diethyl amino group and a carbon alkyl chain of 2 carbon atom length, which includes a halogen at the terminal end thereof. The amendments to claim 1 result in a specific chemical structure which is new in light of the chemical structures defined in the cited Toivola et al. patent.

The specific chemical structure of claim 1 is also distinguished over those structures defined in Foster et al., as Foster et al. relates to hydroxy derivatives of tamoxifen and the claimed derivative is not a hydroxy derivative.

The Watanabe et al. article discloses human metabolites of toremifene, which include an N,N dimethyl amino structure, an N-demethyl toremifene structure, a 4-hydroxy toremifene structure, an N-demethyl-4-hydroxy toremifene structure and a 4,4'-d, hydroxy toremifene structure. No N,N diethyl amino derivatives of tamoxifen are disclosed, and therefore the claimed derivative of tamoxifen is novel.

The D'Argy et al. abstract (1989) describes a [<sup>3</sup>H] toremifene, particularly in regard to its tissue distribution. Toremifene has an N,N-dimethyl ethyl amine citrate chemical structure. In contrast, the claimed tamoxifen derivative structure includes an N,N-diethyl amino structure. The claimed derivatives are thus novel over the chemical structures of D'Argy.

The Kangas et al. abstract (1989) again relates to a toremifene structure, and the biodistribution of radiolabeled toremifene in tissues and tumors. These derivatives were described as having limited use in diagnosing and imaging

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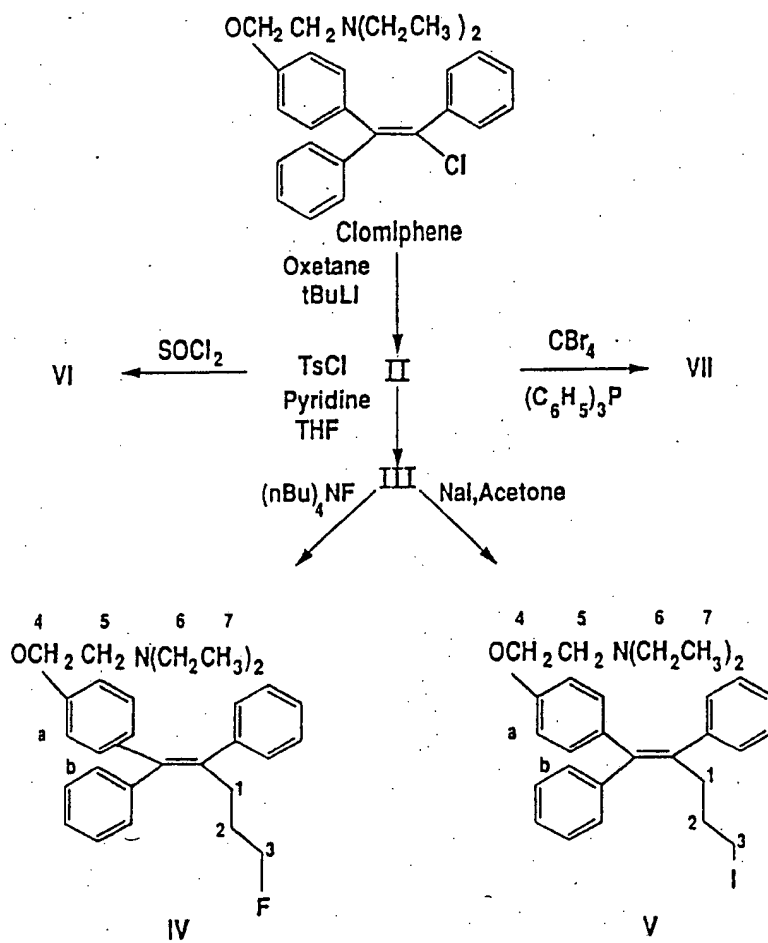
estrogen receptor-rich breast tumors in humans. Again, the toremifene structure includes an N,N-dimethyl ethylamine citrate chemical structure, while the claimed derivatives have an N,N-diethyl amino group.

Former claim 19 (now claim 16) has also been amended to include an N,N-diethyl amino structure. The chemical structure of this derivative is novel compared to the N,N-dimethyl amino and toremifene derivatives of Toivola et al., Foster et al., Watanabe, D'Argy and Kangas et al. for the reasons afore-described. The radiolabeled derivatives provide surprising efficacy for use as radiodiagnostic agents as they have an enhanced target tissue specificity for estrogen-rich tissues. Moreover, the claimed derivative structure has an enhanced receptor binding affinity and potency by virtue of its N,N-diethyl structure, as the absence of halogen at the phenolic ring preserves the conformational activity of the derivative for attachment to estrogen receptors, as well as rendering the molecule less susceptible to halogen elimination.

Attached are replacement pages 56-65 with the amended claims and abstract. Former claim 12 is now claim 10. Formerly numbered claims 11-50 are now claims 9-47.

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## Structures of Tamoxifen and Derivatives



## Synthetic Scheme of Tamoxifen Derivatives

Fig. 1

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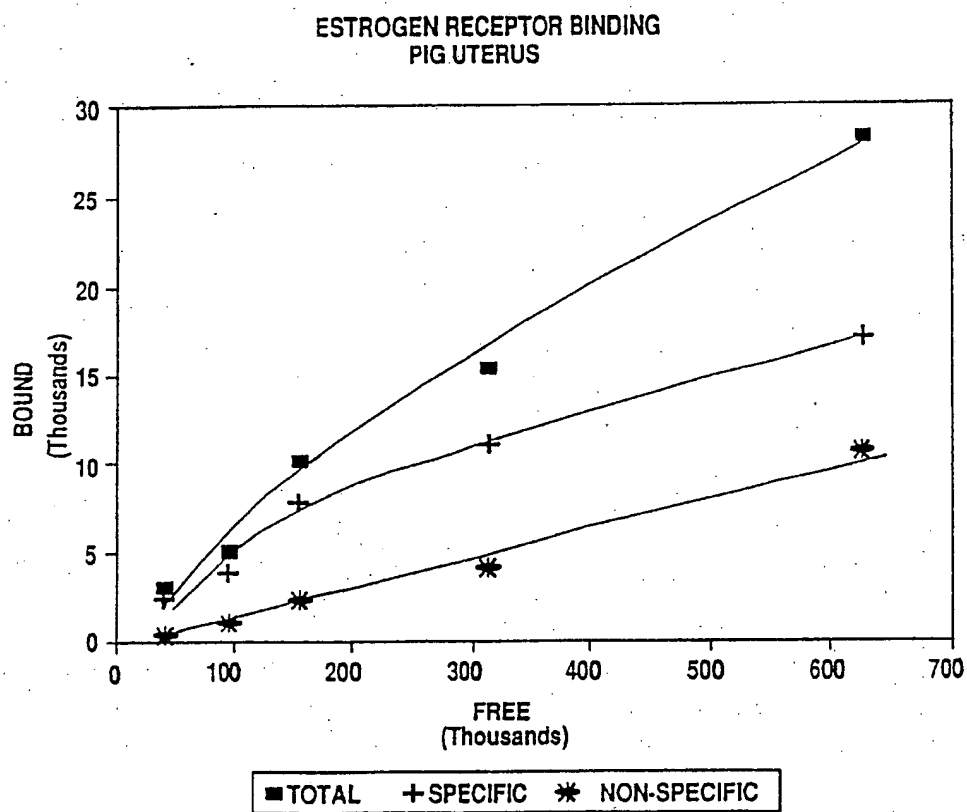
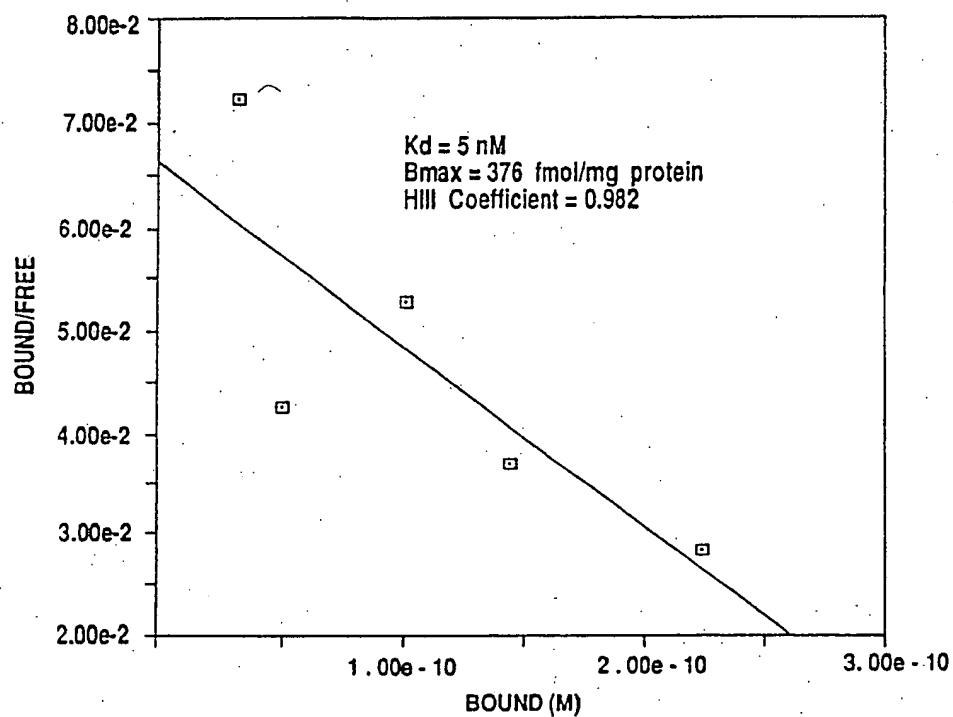


Fig. 2

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## SCATCHARD ANALYSIS



In Vitro Saturation Experiment and Scatchard Plot  
for Estrogen Receptor Assay

Fig. 3

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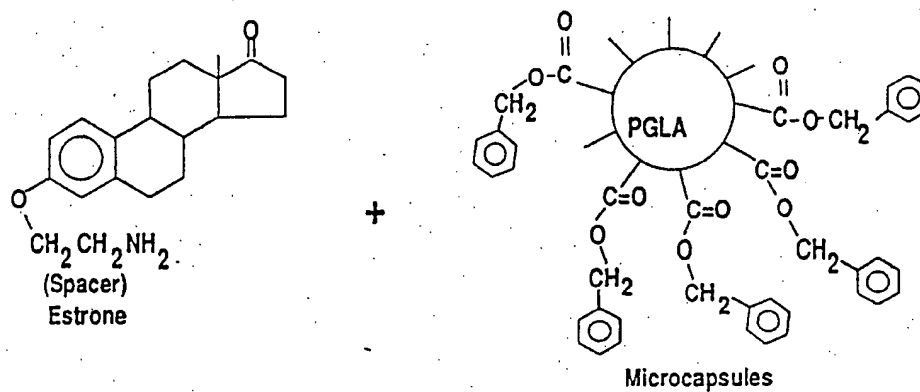


Fig. 4A

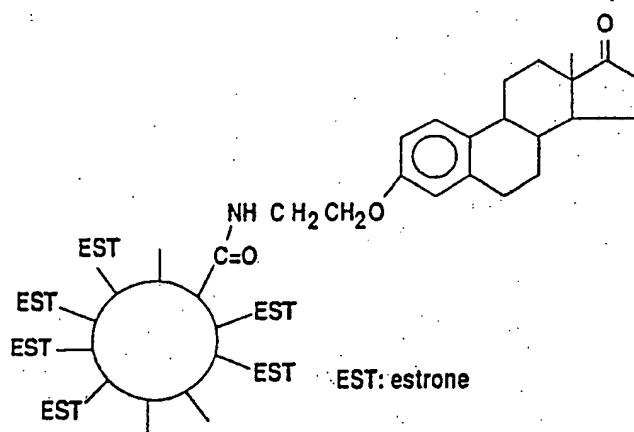


Diagram of Coupling Reaction Between Estrone (or Tamoxifen) and Polglutamate (PGLA)

Fig. 4B

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CH<sub>3</sub>CN / H<sub>2</sub>O/Et<sub>3</sub>N (85/15/1)  
FLOW RATE 1ml/min  
C-18 (RADIAL-PAK, 8x100mm)

- A. RADIOCHEMICAL PURITY  
(15  $\mu$ Ci; > 96%)  
B. MIXTURE OF 4 $\mu$ g UNLABELED  
F-TX AND 15  $\mu$ Ci TRACER  
C. CHEMICAL PURITY (UV MONITOR)

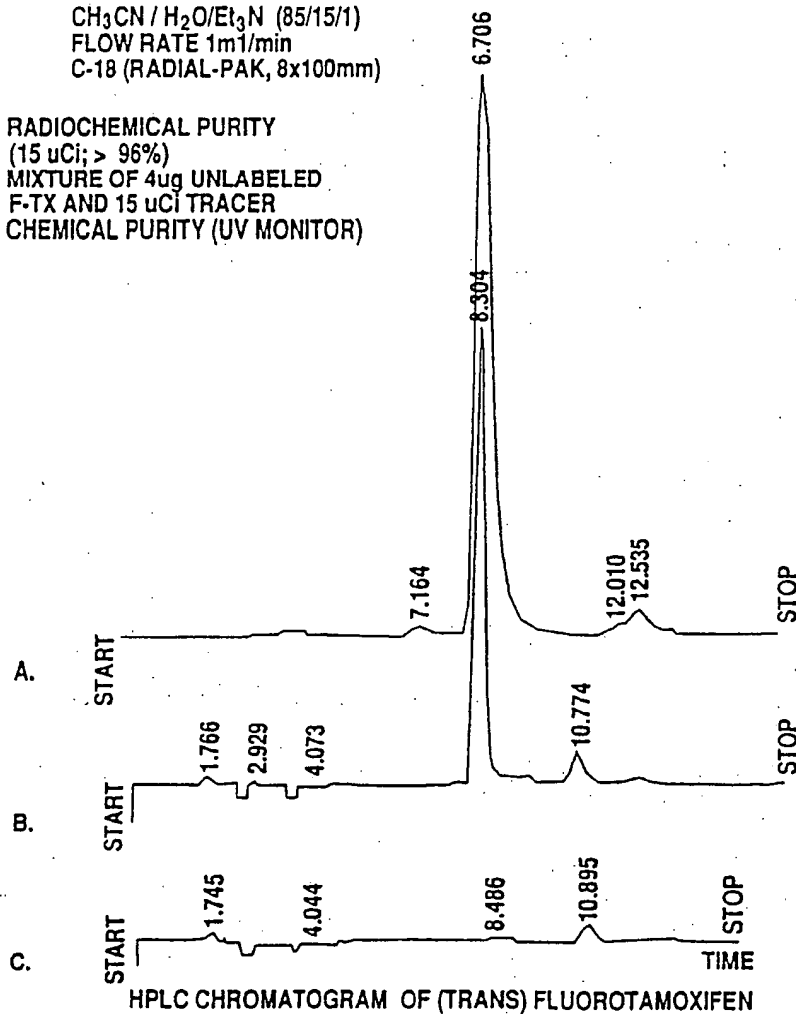


Fig. 5

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(cis)-N,N-Diethylfluoromethyltamoxifen

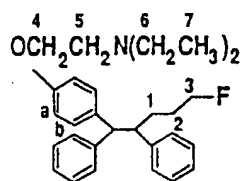


Fig. 6B

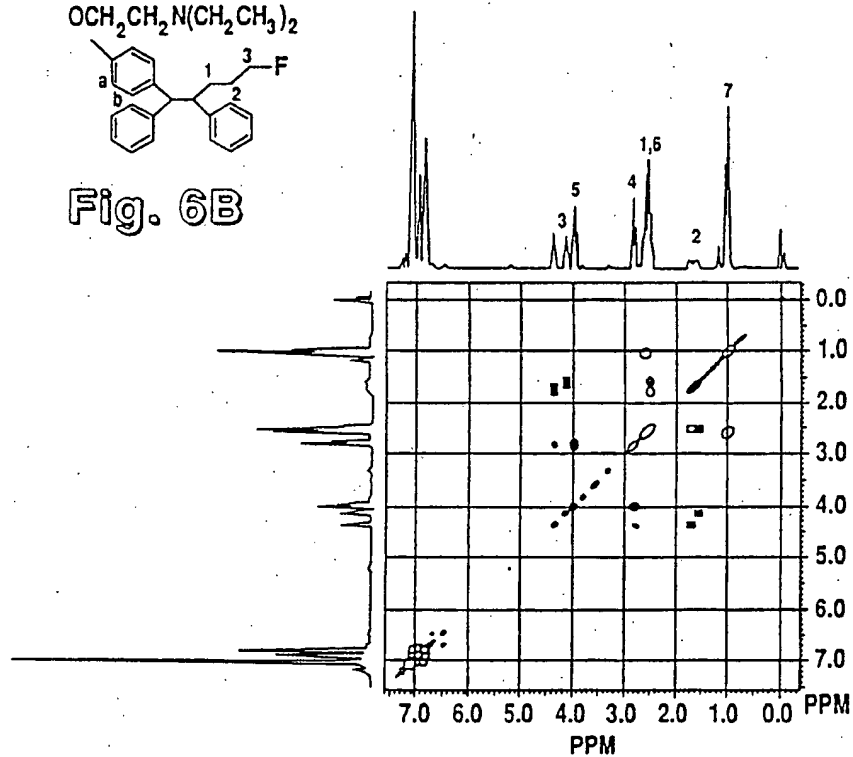


Fig. 6A

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(trans)-N,N-Diethylfluoromethyltamoxifen

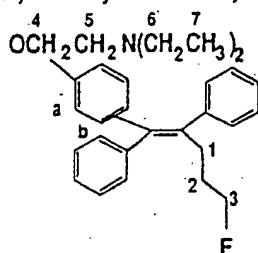


Fig. 7B

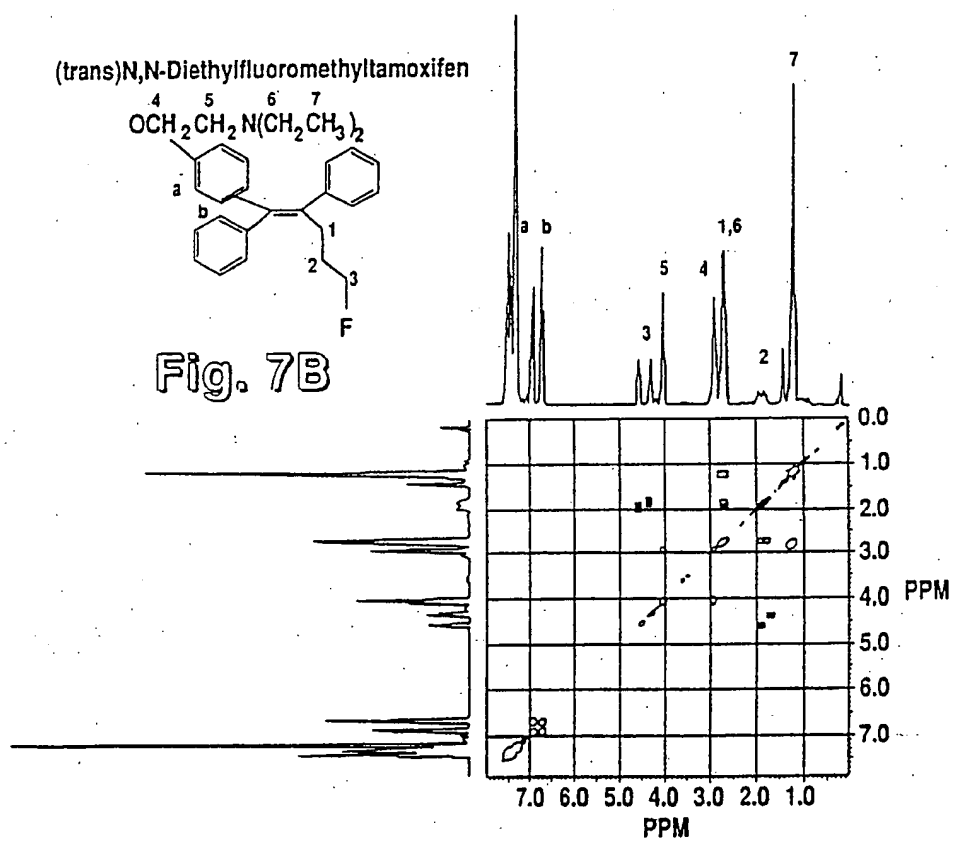


Fig. 7A

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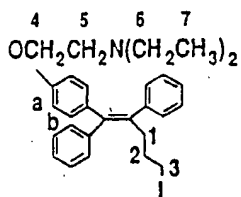


Fig. 8B

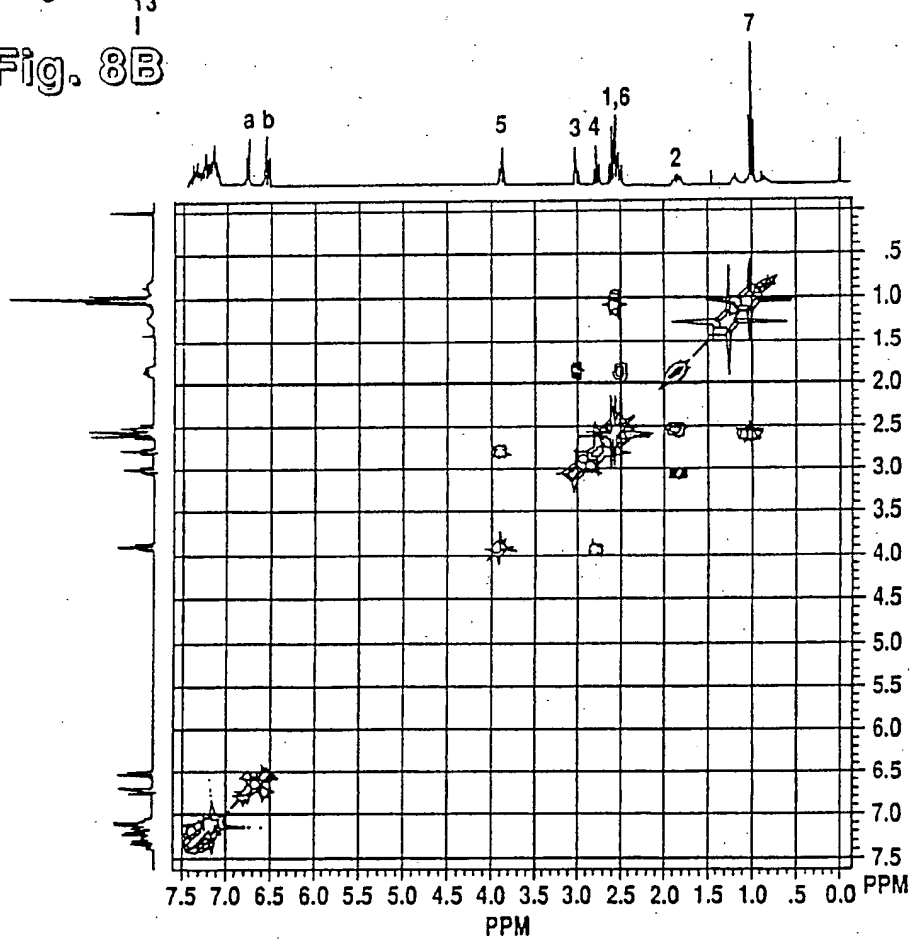


Fig. 8A

SUBSTITUTE SHEET

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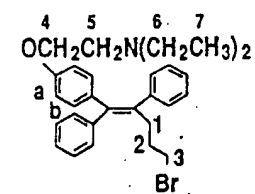


Fig. 9B

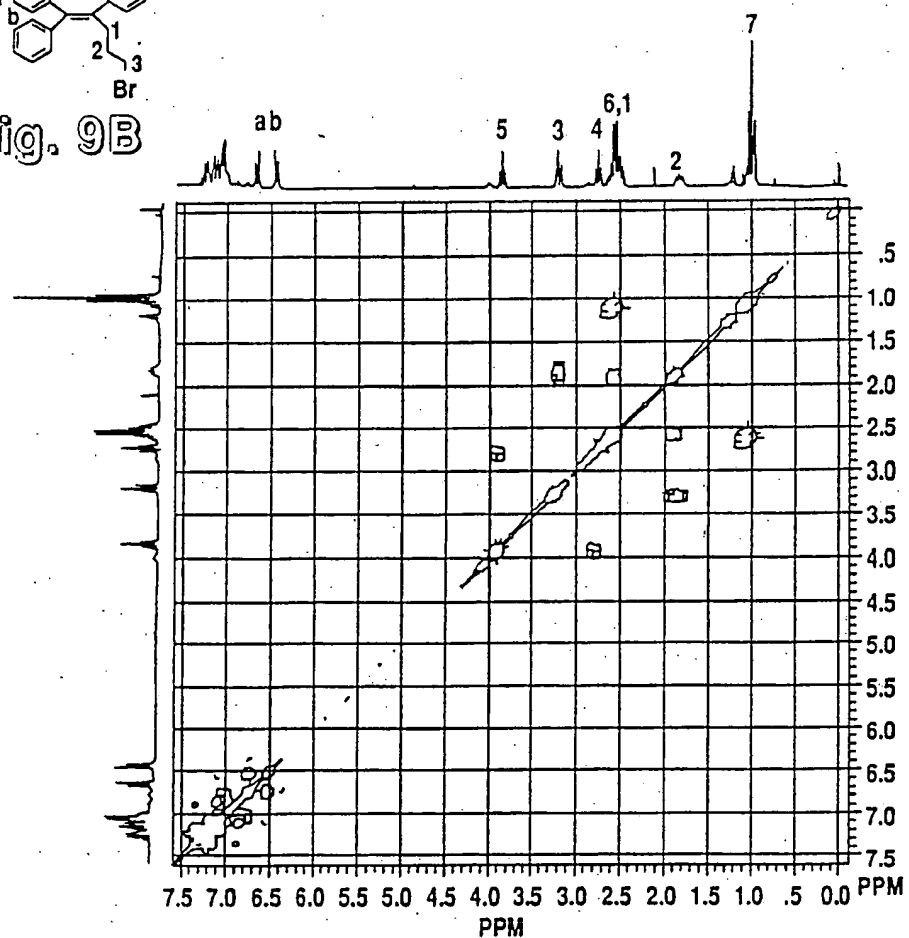


Fig. 9A

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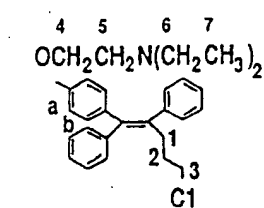


Fig. 10B

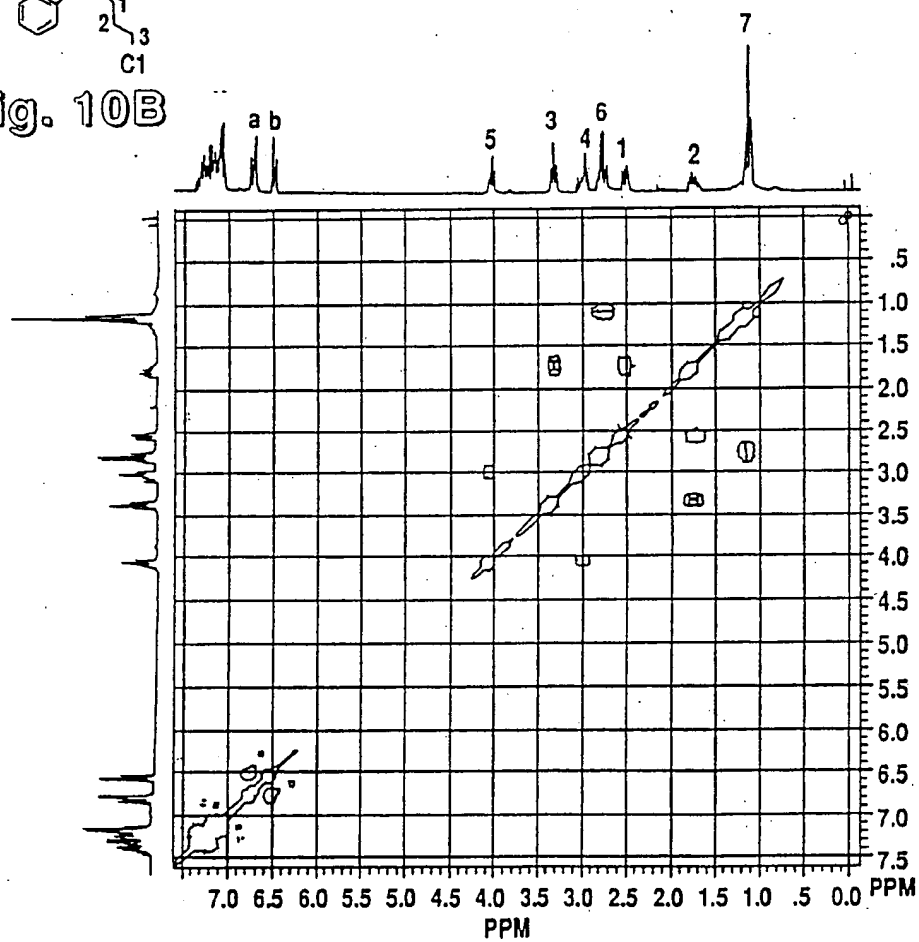



Fig. 10A

SUBSTITUTE SHEET

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 91/07150

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (If several classification symbols apply, indicate all) <sup>6</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int.C1.5	C 07 C 217/18	C 07 B 59/00
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>7</sup>		
Classification System	Classification Symbols	
Int.C1.5	C 07 C 217/00	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup></b>		
Category *	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
X	EP,A,0095875 (FARMOS GROUP LTD) 7 December 1983, see page 29, lines 11-13; claims; examples 10c, 28 ---	1,2,9, 10,19- 21
X	Journal of Medicinal Chemistry, volume 28, no. 10, October 1985, American Chemical Society (Washington, US) A.B. Foster et al.: "Hydroxy derivatives of tamoxifen", pages 1491-1497, see page 1493, column 1, paragraph 4 - column 2, paragraph 1; page 1496, column 2, lines 6-30 ---	1,4,9, 10,19
X	Journal of Chromatography, volume 497, 29 December 1989, Elsevier Science Publishers B.V. (Amsterdam, NL) N. Watanabe et al.: "Liquid chromatographic-atmospheric pressure ionization mass spectrometric analysis of toremifene metabolites in human urine", pages 169-180, see the whole document --- -/-	1,2,19
<p>* Special categories of cited documents: <sup>10</sup></p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"A" document member of the same patent family</p>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
07-02-1992	27.02.92	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	Nicole De Bie 	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	Chemical Abstracts, volume 110, no. 3, 16 January 1989 (Columbus Ohio, US) R.D'Argy et al.: "Comparative double-tracer whole-body autoradiography: uptake of carbon-11-, fluorine-18- and tritium-labeled compounds in rat tumors", see page 259, abstract no. 20581h, & Nuclear Medicine and Biology, 1988, 15(5), 577-85	1,2,19
A	---	23-36, 38-50
X	Chemical Abstracts, volume 110, no. 25, 19 June 1989, (Columbus, Ohio, US) L. Kangas et al.: "Biodistribution and scintigraphy of 11C-toremifene in rats bearing DMBA-induced mammary carcinoma", see page 10, abstract no. 224948t, & Pharmacology and Toxicology (Copenhagen) 1989, 64(4), 373-7	1,2,19
A	---	23-36, 38-50
A	EP,A,0054168 (KLINGE PHARMA GMBH) 23 June 1982, see claims; examples	1-22,37
A	EP,A,0260066 (NATIONAL RESEARCH DEVELOPMENT CORPORATION) 16 March 1988, see the whole document	1-50
P,X	Chemical Abstracts, volume 113, no. 17, 22 October 1990, (Columbus, Ohio, US) S. Hannu et al.: "Metabolism of toremifene in the rat", see page 10, abstract no. 144793k, & J. Steroid Biochem. 1990, 36(3), 211-15	1,2,19
A	-----	23-36, 38-50

## FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. ☒ OBSERVATION WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE <sup>1</sup>

This International search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim numbers  
Authority, namely: because they relate to subject matter not required to be searched by this

Although claims 19-22 and 38-47 are directed to a method of treatment of the human or animal body as well as a diagnostic method the search has been carried out and based on the alleged effects of the compound.

2. ☐ Claim numbers  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim numbers  
the second and third sentences of PCT Rule 6.4(a), because they are dependent claims and are not drafted in accordance with

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING <sup>2</sup>

This International Searching Authority found multiple inventions in this International application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

## Remark on Protest

- ☐ The additional search fees were accompanied by applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO.

US 9107150  
SA 53097

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 24/02/92. The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A- 0095875	07-12-83	GB-A- 2126576	28-03-84
		AT-B- 383344	25-06-87
		AU-B- 556608	13-11-86
		AU-A- 1494683	19-01-84
		CA-A- 1185977	23-04-85
		JP-A- 58216129	15-12-83
		JP-A- 3007239	14-01-91
		SU-A- 1508955	15-09-89
		US-A- 4996225	26-02-91
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		JP-A- 63077845	08-04-88
		US-A- 4839155	13-06-89

EP FORM P027

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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